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SOME ASPECTS OF THE USE OF THE ANNUAL RINGS OF TREES IN CLIMATIC STUDY[1]

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I. AFFILIATIONS

NATURE is a book of many pages and each page tells a fascinating story to him who learns her language. Our fertile valleys and craggy mountains recite an epic poem of geologic conflicts. The starry sky reveals gigantic suns and space and time without end. The human body tells a story of evolution, of competition and survival. The human soul by its scars tells of man's social struggle.

The forest is one of the smaller pages in nature's book, and to him who reads it too tells a long and vivid story. It may talk industrially in terms of lumber and firewood. It may demand preservation physiographically as a region conserving water supply. It may disclose great human interests ecologically as a phase of plant succession. It may protest loudly against its fauna and parasites. It has handed down judicial decisions in disputed matters of human ownership. It speaks everywhere of botanical language, for in the trees we have some of the most wonderful and complex products of the vegetable kingdom.

The trees composing the forest rejoice and lament with its successes and failures and carry year by year something of its story in their annual rings. The study of their manner of telling the story takes us deeply into questions of the species and the individual, to the study of pests, to the effects of all kinds of injury, especially of fire so often started by lightning, to the closeness of grouping of the trees and to the nearness and density of competing

[1] Address of the President of the Southwestern Division of the American Association for the Advancement of Science, Tucson, Arizona, January 26, 1922.

vegetation. The particular form of environment which interests us here, however, is climate with all its general and special weather conditions. Climate is a part of meteorology, and the data which we use are obtained largely from the Weather Bureau. Much helping knowledge needed from meteorology has not yet been garnered by that science. For example, the conditions for tree growth are markedly different on the east and west sides of a mountain or on the north and south slopes. The first involves difference of exposure to rain-bearing winds, and the second means entirely different exposure to sun and shade. The latter contrast has been studied on the Catalina Mountains by Forrest Shreve. Again, the Weather Bureau stations are largely located in cities and therefore we can not get data from proper places in the Sierra Nevada Mountains of California, where the Giant Sequoia lives. Considering that this Big Tree gives us the longest uninterrupted series of annual climatic effects which we have so far obtained from any source, it must be greatly regretted that we have no good modern records by which to interpret the writing in those wonderful trees, and, so far as I am aware, no attempt is yet being made to get complete records for the future.

In reviewing the environment, one must go another step. One of the early results of this study was the fact that in many different wet climates the growth of trees follows closely and sometimes fundamentally certain solar variations. That means astronomical relationship. It becomes then an interesting fact that the first two serious attempts to trace climatic effects in trees were made by astronomers. I do not know exactly what inspired Professor Kapteyn, the noted astronomer of Groningen, Holland, to study the relation of oak rings to rainfall in the Rhineland, which he did in 1880 and 1881 (without publishing), but for my own case I can be more explicit. It was a thought of the possibility of determining variations in solar activity by the effect of terrestrial weather on tree growth. This, one notes, assumed an effect of the sun on our weather, a view which was supported twenty years ago by Bigelow.

But the possible relationship of solar activity to weather is a part of a rather specialized department of astronomical science, called astrophysics. And there is a great deal of help which one wants from that science, but which one can not yet obtain; for example, the hourly variations in the solar constant. I would like to know whether the relative rate of rotation and the relative temperatures of different solar latitudes vary in terms of the 11-year sunspot period. These questions have to do with some of the theories proposed in attempting to explain the sunspot periodicity.

We do not know the cause of the 11-year sunspot period. Here then is work for the astronomers.

Yet another important contact has this study developed. The rings in the beams of ancient ruins tell a story of the time of building, both as to its climate and the number of years involved and the order of building. This is anthropology. It will be mentioned on a later page.

Viewed through the present perspective, there is one way of expressing the entire work which shows more clearly its human end, a contact always worth emphasizing. If the study works out as it promises, it will give a basis of long-range weather forecasting of immense practical value for the future and of large scientific value in interpreting the climate of the past. This statement of it carries to all a real idea of the central problem.

II. Yearly Identity of Rings

The one fundamental quality which makes tree rings of value in the study of climate is their yearly identity. In other words, the ring series reaches its real value when the date of every ring can be determined with certainty. This is the quality which is often taken for granted without thought and often challenged without real reason. The climatic nature of a ring is its most obvious feature. There is a gradual cessation of the activity of the tree owing to lowered temperature or diminished water supply. This causes the deposition of harder material in the cell walls, producing in the pine the dark hard autumn part of the ring. The growth practically stops altogether in winter and then starts off in the spring at a very rapid rate with soft white cells. The usual time of beginning growth in the spring at Flagstaff (elevation 7,000 feet) is in late May or June and is best observed by Dr. D. T. MacDougal's "Dendrograph," which magnifies the diameter of the tree trunk and shows its daily variations. This spring growth depends upon the precipitation of the preceding winter and the way it comes to the tree. Heavy rains have a large run-off and are less beneficial than snow. The snow melts in the spring and supplies its moisture gradually to the roots as it soaks into or moves through the ground. There is evidence that if the soil is porous and resting on well cracked limestone strata, the moisture passes quickly and the effect is transitory, lasting in close proportion to the amount of rain. Trees so placed are "sensitive" and give an excellent report of the amount of precipitation. Such condition is commonly found in northern Arizona over a limestone bed rock. If the bed rock is basalt or other igneous material the soil over it is apt to be clay. The rock and the clay sometimes hold water until the favorable season is past and the tree growth de-

pends in a larger measure on other factors than the precipitation. For example, the yellow pines growing in the very dry lava beds at Flagstaff show nearly the same growth year after year. It is sometimes large, but it has little variation. Such growth is "complacent."

Yearly identity is disturbed by the presence of too many or too few rings. Surplus rings are caused by too great contrast in the seasons. The year in Arizona is divided into four seasons, two rainy and two dry. The cold rainy or snowy season is from December to March, and the warm tropical summer, with heavy local rainfall, occurs in July and August. Spring and autumn are dry, the spring being more so than the autumn. If the snowfall of winter has not been enough to carry the trees through a long dry spring, the cell walls in June become harder and the growing ring turns dark in color as in autumn. Some trees are so strongly affected that they stop growing entirely until the following spring. A ring so produced is exceptionally small. But others near-by may react to the summer rains and again produce white tissue before the red autumn growth comes on. This second white-cell structure is very rarely as white as the first spring growth and is only mistaken for it in trees growing under extreme conditions, such as at the lowest and dryest levels which the yellow pines are able to endure. Such is the condition at Prescott or at the 6,000-7,000 ft. levels on the mountains about Tucson. A broken and scattered rainy season may give as many as 3 preliminary red rings before the final one of autumn. In a few rare trees growing in such extreme conditions, it becomes very difficult to tell whether a ring is formed in summer or winter (that is, in late spring or late autumn). Doubling has become a habit with that particular tree—a bad habit—and the tree or large parts of it cannot be used for the study of climate.

But let us keep this clearly in mind: This superfluous ring formation is the exception. Out of 67 trees collected near Prescott, only 4 or 5 were discarded for this reason. Out of perhaps two hundred near Flagstaff, none have been discarded for this reason. Neodly a hundred yellow pines and spruces from northwestern New Mexico have produced no single case of this difficulty. The sequoias from California, the Douglas firs from Oregon, the hemlocks from Vermont and the Scotch pines from north Europe give no sign of it. On the other hand, 10 out of 16 yellow pines from the Santa Rita Mountains south of Tucson have had to be discarded and the junipers of northern Arizona have so many suspicious rings that it is almost impossible to work with them at all. Cypress trees also give much trouble.

The other difficulty connected with yearly identity is the omission of rings. Missing rings occur in many trees without lessening the value of the tree unless there are extensive intervals over which the absence produces uncertainty. A missing ring here and there can be located with perfect exactness and causes no uncertainty of dating. In fact, so many missing rings have been found after careful search that they often increase the feeling of certainty in the dating of rings.

Missing rings occur when autumn rings merge together in the absence of any spring growth. This rarely if ever occurs about the entire circumference of the tree. There are a few cases in which, if the expression may be excused, I have traced a missing ring entirely around a tree without finding it. I have observed many cases in which the missing ring has been evident in less than 10 per cent. of the circumference. Some are absent in only a small part of their circuit. I have observed change in this respect at different heights in the tree, but have not followed that line of study further. It is beautifully shown in the longitudinally bisected tree.

One sees from this discussion what the probable errors may be in mere counting of rings. In the first work on the yellow pines the dating was done by simple counting. Accurate dating in the same trees (19 of them) later on showed that the average error in counting through the last 200 years was 4 per cent., due practically always to missing rings. A comparison in seven sequoias between very careful counting and accurate dating in 2,000 years shows an average counting error of 35 years, which is only 1.7 per cent.

Full confidence in yearly identity really comes from another source. The finding of similar distribution of large and small rings in practically all individuals of widely scattered groups of trees over great periods of time has been evidence enough to make us sure. This comparison process of groups of rings in different trees has received the rather clumsy name of "cross-identification." Cross-identification was first successful in the 67 Prescott trees, then was carried across 70 miles to the big Flagstaff groups. Later it was found to extend 225 miles further to southwestern Colorado with extreme accuracy, 90 per cent. perhaps. This is over periods of more than 250 years. Catalina pines from near Tucson have a 50 per cent. likeness to Flagstaff pines. There are many points of similarity in the last 200 years and many differences. Santa Rita pines are less like the Flagstaff pines than are the Catalinas. In comparison with the California sequoias, differences become more common. The superficial resemblance to Arizona pines is 5 or 10

per cent. only. That is, out of every 10 or 20 distinctive rings with marked individuality, one will be found alike in California and Arizona. For example, A. D. 1407, 1500, 1580, 1632, 1670, 1729, 1782, 1822 and 1864 are small in Arizona pines and California sequoias. While only a few extreme individual years thus match, there are correspondences in climatic cycles to which attention will be called later.

Cross-identification is practically perfect amongst the sequoias stretching across 15 miles of country near General Grant National Park. Trees obtained near Springville, some 50 miles south, show 50 to 75 per cent. resemblance in details to the northern group. This was far more than enough to carry exact dating between these two localities. Cross-identification in some wet climate groups was extremely accurate. A group of 12 logs floating in the river-mouth at Geffle, Sweden, showed 90 to 95 per cent. resemblance to each other. The range was 100 to 200 years and there were no uncertain years at all. The same was true of some 10 tree sections on the Norwegian coast and of 13 sections cut in Eberswalde in Germany. A half dozen sections cut in a lumber yard in Munich did not cross-identify with each other. A group of 5 from a lumber yard in Christiania was not very satisfactory. The vast majority, however, have been absolutely satisfactory in the matter of cross-identification. Nothing more is needed to make the one ring a year ideal perfectly sure, but if there were, it would come in such tests as frequently occur in checking the known date of cutting or boring, with a set of rings previously dated. That has been done on many occasions in Arizona and California. To give final assurance, the record in the yellow pine was compared with statements of good and bad years, and years of famine, flood and cold, reported in Bancroft's "History of Arizona and New Mexico," and it was found that his report identified with the character of the growth in the corresponding years of the trees.

Three results may be noted before leaving this important subject. Deficient years extend their character across country with more certainty than favorable years. A deficient year makes an individual ring small compared to those beside it. Large rings, on the other hand, are more apt to come in groups and so do not have quite the same individuality. Nor are they as universal in a forest. If they occur at a certain period in one tree, the chances are about 50 per cent. that the corresponding years in the neighboring trees will be similarly enlarged. If, however, a very small ring occurs in a tree, the chances are over 90 per cent. that the neighboring trees will show the same year small.[8]

Second, with many groups of trees where the resemblance be-

tween their rings is strikingly exact, a small number of individuals such as 5 will answer extremely well for a record, and even fewer will give valuable and reliable results. But the central part of a tree has larger growth and is less sensitive than the outer part. Its character is somewhat different. To get a satisfactory representation through several centuries, therefore, it is better to combine younger trees with older ones to get a more even and constant record of climatic conditions.

The third thought is this. The spreading of a certain character over many miles of country stamps it in almost every case as climatic in origin, because climate is the common environment over large areas.

III. Number and Location of Trees

The whole number of trees used is nearly 450 and includes cone-bearing trees from Oregon, California, Arizona, New Mexico, Colorado, Vermont, England, Norway, Sweden, Germany and Bohemia. The total number of rings dated and measured is well over 100,000. The average ages found in these various trees are very interesting. The European groups reach for the most part about 90 years, although one tree in Norway showed 400 years of age, and 15 were found beginning as early as 1740. The Oregon group of Douglas firs goes back to about 1710, the Vermont hemlocks reach 1654, the Flagstaff yellow pines give a number of admirable records from about 1400.

The oldest trees, of course, were the great sequoias from the Sierra Nevada Mountains in California. They were found to have ages that formed natural groups, showing probably a climatic effect. There are very few under 700 years old (except the young ones which have started since the cutting of the Big Trees). A number had about that age. The majority of the trees scatter along in age from 1,200 up to about 2,200 years, at which age a large number were found, one or two were found of 2,500 years, one of 2,800, one of 3,000, one at just under 3,100, and the oldest of all just over 3,200. The determination of this age of the older sequoias in the present instance is not merely a matter of ring counting, but depends upon the inter-comparison of some 55,000 rings in thirty-five trees. In 1919 a special trip was made to the Big Trees and samples from a dozen extra trees obtained in order to decide the case of a single ring, 1580 A. D., about which there was some doubt, and it was apparent that the ring in question stood for an extra year. This was corrected and it now seems likely that there is no

[3] This success in cross-identification applies to the groups examined. A recent group of coast redwoods from Santa Cruz, California, present a multitude of difficulties.

mistake in dating through the entire sequence of years, but if not correct the error is certainly very small.

IV. Topography

The late Professor W. R. Dudley of Stanford University in his charming essay on the "Vitality of the Sequoia" refers to the fact that the growth of the Big Trees depends in a measure on the presence of a brook near by. This agrees with my own observations. Size is far from a final indication of age. The General Grant tree which has no running water near it and is the largest in the Park of that name. has a burnt area on one side in which the outer rings are exposed, allowing an estimate of its average rate of recent growth. From much experience with the way the sequoia growth is influenced by age, it was possible to assign 2,500 years as the approximate time it took this giant to reach its present immense diameter of close to 30 feet. But about three miles west near a running brook is a stump which is over twenty-five feet in diameter, but is only about 1,500 years old. That is the effect of contact with an unfailing source of water.

Perhaps the most general characteristic which stands out in the different groups of dry-climate trees is a close relationship of this kind between the topography and the growth produced. For that reason, I have visited the site of every dry-climate group and indeed have examined the stumps of almost every tree in my collection.

It was found that dry-climate trees which grew in basins with a large and constant water supply, and this refers especially to the sequoias, usually produced rings without much change in size from year to year. This character of ring is called "complacent." The opposite character is the "sensitive" ring where a decided variation is shown from year to year. Sensitive trees grow on the higher elevations where the water supply is not reliable and the tree must depend almost entirely on the precipitation during each year. Such trees grow near the tops of ridges or are otherwise separated from any collection of water in the ground. In case of the basin trees, one could be sure that a ring was produced every year, but owing to the lack of individuality in the rings for certain years, it was difficult to compare trees together and produce reliable data. In case of the sensitive tree growing in the uplands there was so much individuality in the rings that nearly all of the trees could be dated with perfect reliability, but in extreme cases the omission of rings in a number of trees required special study. Of course, these cases were easily settled by comparison with other trees growing in intermediate localities.

Trees growing in the dry climate of Arizona at an altitude where they have the utmost difficulty in getting water to prolong life become extraordinarily sensitive. In the same tree one finds some rings several millimeters across and others microscopic in size or even absent.

In order to express this different quality in the trees a criterion called mean sensitivity is now under investigation. It may be defined as the difference between two successive rings divided by their mean. Such quotients are averaged over each decade or other period desired and are believed to depend in part on the relative response of the trees to climatic influences. The great sensitiveness of the yellow pines as compared with the best sequoias is evident in any brief comparison of dated specimens.

V. Instruments

In the course of this long attention to the rings of trees and in studying such a vast number of them, special tools to secure material and to improve and hasten the results have very naturally been adopted or developed. One goes into the field well-armed, carrying a flooring saw with its curved edge for sawing half across the tops of stumps, a chisel for making numbers, numerous paper bags for holding fragments cut from individual trees, a recording note book, crayon, a shoulder bag, camera and especially a kindly, strong-armed friend to help in the sawing. In the last eighteen months the Swedish increment borer has been used extensively to get records from living pine trees. Hard woods and juniper are too tough. It has previously been considered that the little slender cores, smaller than a pencil, so obtained, would hardly be worth working on. But the method of mounting them has been raised to such a degree of efficiency, and the collection of material becomes so rapid that the deficient length and the occasional worthless specimen are counterbalanced. Besides, it is often easy to supplement a group of increment cores by some other form of specimen extending back to greater age. The Mount Lemmon group, near Tucson, has eight cores giving a good record from about 1725 to the present time; a saw cutting from a large stump in Summerhaven carries the record back 150 years earlier. It should, however, be supported by at least one more long record and this can be done by the tubular borer described next.

The tubular borer was designed especially for the dried and sometimes very hard logs in the prehistoric ruins. It works well on pine trees and junipers. It gives a core an inch in diameter, which means a far better chance of locating difficult rings than in the increment borer cores which are only one fifth of that diameter. The borer is a one-inch steel tube with small saw-teeth on one

end and a projection at the other for holding in a common brace. A chain drill attachment is also provided to help in forcing the drill into the wood. The difficulty with this borer is the disposal of sawdust and the extraction of the core. For the former, a separate hole is bored with a common auger just below the core (if in an upright tree) and in advance of it to catch the sawdust. The core is broken off every three inches and pulled out to make more room for the sawdust. To extract the core a small steel rod is provided with a wedge at one end and a screw at the other. One- and two-foot tubes are carried so that it is possible to reach the centers of most pine trees. It would not be difficult to develop an instrument much more efficient than this and it should be done. Soon a borer will be needed to pass through a 35-foot tree or to sound the depths of the great Tule trees of southern Mexico.

The tools just mentioned are technical, yet in no sense complex. A measuring instrument has just been completed whose usefulness will be extensive and whose details of construction are too complex for present description. It is for measuring the width of rings. It makes a record as fast as one can set a micrometer thread on successive rings. The record is in the form of a plot drawn in ink to scale on coordinate paper so that the values can be read off from it at once for tabulation. This form of record was desired because individual plots have long been made to help in selecting the best trees and in studying their relation to topography. The instrument as constructed magnifies 20, 40 or 100 times, as desired. It can be attached to the end of an astronomical telescope and used as a recording micrometer capable of making a hundred or more settings before reading the values. It seems possible that it will have other applications than the ones here mentioned.

Another instrument of entirely different type has been developed here since 1913. Its general principle has been published and will not be repeated, but in the last three years it has been entirely rebuilt in a more convenient form through the generosity of Mr. Clarence G. White of Redlands. This instrument is now known as the White Periodograph. It could be called a cycloscope or cyclograph. Its purpose is to detect cycles or periods in any plotted curve. It differs from previous instruments performing harmonic analysis in that it is designed primarily to untangle a complex mixture of fairly pronounced periods while others determine the constants of a series of harmonic components. For example, the periodograph can be applied to a series of rainfall records to find if there are any real periods operating in a confused mixture. It is also designed to get rid of personal equation and to get results quickly. The instrument as reconstructed is far more convenient

and accurate in use and has already given important results. It enables one to see characteristics in tree growth variation which are not visible to the unaided eye. It is specially arranged now to give what I have called the differential pattern or cyclogram because this pattern not only tells the periods or cycles when properly read but shows the variations and interferences of cycles and possible alternative readings. Tests on the accuracy of solutions by this instrument show that its results correspond in precision to least square solutions.

VI. Correlations

It is no surprise that variations in climate can be read in the growth rings of trees, for the tree ring itself is a climatic product. It is an effect of seasons. The geologists use the absence of rings in certain primitive trees as an indication that no seasons existed in certain early times. Whatever may have been the cause of that absence, we recognize that the ring is caused primarily by changes in temperature and moisture. Now if successive years were exactly alike, the rings would be all of the same size with some alteration with age and injury. But successive years are not alike and in that difference there may be some factor which appeals strongly to the tree. In northern Arizona, with its limited moisture and great freedom from pests and with no dense vegetable population, this controlling factor may reasonably be identified as the rainfall. If the trees have all the moisture they can use, as in north Europe about the Baltic Sea and other wet climates, we look for it in something else. It could be—I do not say that it is—some direct form of solar radiation. It could be some special combination of the ordinary weather elements with which we are familiar. Shreve has studied this phase in the Catalinas. If the abundance of moisture is so great as actually to drown the tree, then decrease in rainfall which lowers the water table below ground will be favorable. A fact often forgotten is that more than one factor may enter into the tree rings at the same time, for example, rainfall, temperature and length of growing season. These may be isolated in two ways. We may select a special region, as northern Arizona, where nature has standardized the conditions, leaving one of them, the rainfall, of especial importance. Or we may isolate certain relationships as in any other investigation, by using large numbers of observations, that is, many trees, and averaging them with respect to one or another characteristic. For example, I can determine the mean growth curve of the Vermont hemlocks and then compare it separately with rainfall and solar activity, and I may, and do, find a response to each. For that reason, I have felt quite justified in seeking first the correlation with moisture. A temperature cor-

relation doubtless exists and in fact has been noted, but its less minute observance does not lessen the value of the rainfall relationship.

The first real result obtained in this study was in 1906 when it became apparent that a smoothed curve of tree growth in northern Arizona matched a smoothed curve of precipitation in southern California since 1860. That degree of correlation is now extensively used in the Forest Service. This was followed almost at once by noting a strikingly close agreement between the size of individual rings and the rainfall for the corresponding years since 1898, when the Flagstaff weather station was established. The more detailed comparison between rainfall and ring growth was made with Prescott trees in 1911. Some 67 trees in five groups within ten miles of Prescott were compared with the rainfall at Whipple Barracks and Prescott which had been kept on record since 1867. The result was very interesting. For most years the tree variations agree almost exactly with the rainfall but here and there is a year or two of disagreement. The cause of these variable years will sometime be an interesting matter of study. Taken altogether the accuracy of the tree as a rain-gauge was 70 per cent. But a little allowance for conservation of moisture raised the accuracy to 85 per cent., which is remarkably good. The actual character of this conservation is not evident. At first thought it might be persistence of moisture in the ground, but the character of the mathematical formula which evaluated it allowed a different interpretation, namely, that in a series of poor years the vital activity of the tree is lessened. During the dry period from about 1870 to 1905 or so, the trees responded each year to the fluctuations in rainfall but with less and less spirit. This lessening activity took place at a certain rate which the meteorologists call the "accumulated moisture" curve. This suggested that the conservation was in the tree itself. There is much to be done in this comparison between tree growth and rainfall, but the obstacle everywhere is the lack of rainfall records near the trees and over adequate periods of time. The five Prescott groups showed that in a mountainous country nearness was very important. But the nearest records to the sequoias are 65 miles away and at 5,000 feet lower elevation. The best comparison records for the Oregon Douglas spruce are 25 miles away. It is so nearly everywhere. The real tests must be made with records nearby.

In 1912 while attempting to test this relationship of tree growth to rainfall in north Europe, I found that the Scotch pines south of the Baltic Sea showed a very strong and beautiful rhythm matching exactly the sunspot cycle as far back as the trees ex-

tended, which was close to a century. The same rhythm was evident in the trees of Sweden, and perhaps more conspicuous in spruce than pine. Near Christiania the pines were too variable to show it, but it reappeared on the outer Norwegian coast. To the south near the Alps it disappeared, and in the south of England it was uncertain but probably there. In this country it shows prominently in Vermont and Oregon, but the two American maxima come one to three years in advance of the sunspot maxima. There is evidently an important astronomical relationship whose meaning is not yet clear. It is to be noted that it appears in regions whose trees have an abundance of moisture and it thus appears to be a wet climate phenomenon.

But the correlations do not stop at rain and sunspot periodicity. The pines of northern Arizona which are so sensitive to rainfall show a strong half sunspot period. And on testing it one finds that the rainfall does the same and that these variations are almost certainly related to corresponding temperature variations and to the solar period. Thus, the Arizona trees are related to the weather and the weather is related in a degree at least to the sun. Thus we find evidence in forest trees that the 11-year sunspot period prevails in widely different localities and in many places constitutes the major variation. This introduces us to the study of periodic effects in general.

VII. Cycles

Considering first that cycles as we have just shown are revealed in tree growth, second, that the trees give us accurate historic records for hundreds and even thousands of years, and third, that simple cycles or even some more complex function could give a basis for long range weather forecasting, we recognize the vital importance of this elemental part of the story told by the trees. It was exactly for this purpose that the periodograph was designed and constructed and some ten score curves have been cut out for analysis, after minute preparation of the very best yearly values. In fact the major time for two years has been given to this preparation of material. It is hardly done yet, but it is far enough along to anticipate its careful study in the near future. Our present view may be profoundly modified, but it is safe to say that the sunspot cycle and its double and triple value are very general. The double value, about 22 years, has persisted in Arizona for 500 years, and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last 200 years and in Norway for nearly 400 at least. A one-hundred-year cycle is very prominent throughout the 3,000 years of sequoia record and

also in the 500 years of yellow pine. An hypothesis covering all these sunspot multiples will be tested out in the coming months. Should a real explanation be found a step will have been made toward long-range prediction and an understanding of the relationship of the weather and the sun. Other periods, however, than the multiples of the sunspot period do occur and general analysis shows that different centuries are characterized by different combinations of climatic cycles. This suggests to us a great and interesting problem. If we can establish the way in which different regions act and react at the same time, then it may become possible to determine the age of an ancient buried tree by finding the combination of short cycles its rings display and then determining when this combination or its regional equivalent existed in our historic measuring tape, the great sequoia.

VIII. Prehistoric Records in Trees

A new method of investigating the relative age of prehistoric ruins has been developed in connection with this study of climate by the growth of trees, and is being applied to the remarkable ruins at Aztec, in northwestern New Mexico, with its 450 rooms, now in process of excavation by the American Museum of New York City. The ceilings were built of tree trunks placed across the width of the rooms. Smaller poles were laid across these beams and covered with some kind of brush and a thick layer of earth. The beams used in this ceiling construction are almost entirely of yellow pine or spruce and for the most part are in good condition. Many of the rooms have been hermetically sealed for centuries. The beams which have been buried in dust or adobe or in sealed rooms are well preserved. Only those which have been exposed to the air are decayed.

In 1915 Dr. Clark Wissler of the American Museum offered sections of such beams for special study of the rings, knowing the writer's work upon climatic effects in the rings of trees. This offer was gladly accepted, and some preliminary sections were sent at once from the Rio Grande region. These first sections showed that the pines and spruces were far better than cedars for determining climatic characteristics.

The next lot of sections came from Aztec and was cut from loose beams which had been cleared out of the rubbish heaps. Six of these sections cross-identified so perfectly that it was evident that they had been living trees at the same time. This success led to my visit to Aztec in 1919 and a close examination of this wonderful ruin. It was at once apparent that an instrument was necessary for boring into the beams to procure a complete sample of the rings from center to outside, and that the process must avoid

injuring the beams in any way. Such an instrument was developed in the tubular borer as already described. This tool was sent to Mr. Morris and during 1920 he bored into all the beams at Aztec then available and sent me the cores.

These cores, together with other sections of beams too frail for boring, finally represented 37 different beams in some 20 different rooms scattered along the larger north part of the ruin. Practically all of these show similar rings near the outside, and by counting to the last growth ring of each it was easy to tell the relative dates at which the various timbers were cut.

In order to help in describing given rings in these various sections, a purely imaginary date was assumed for a certain rather large ring which appeared in all the timbers. This was called R. D. (Relative Date) 500, and all other rings earlier or later are designated by this system of relative dates. Many interesting results were evident as soon as the various relative dates were compared. In the first place, instead of requiring many hundreds of years in construction as any one would suppose in looking at the ruin, the larger part of it was evidently erected in the course of ten years, for the dates of cutting the timbers found in the large north side include only eight or nine years. The earliest timbers cut were in the northeast part of the structure. The later timbers are at the northwest, and it is evident that the sequence of building was from the easterly side to the westerly side, ending up with the westerly end and extending toward the south.

In one place beams from three stories, one over the other, were obtained. The top and bottom ceiling timbers were cut one year later than those of the middle ceiling, showing that in vertical construction the three floors were erected in immediate succession. A floor pole from Pueblo Bonito was cut one year later than the latest beam obtained from that ruin.

An even more interesting fact was soon after disclosed. A study of the art and industries of neighboring ruins had satisfied Mr. Nelson and Mr. Morris of the American Museum that some of the ruins in Chaco Canyon, some 50 miles to the south, were not far different in age from those at Aztec. The only beams immediately available from the Chaco Canyon ruins had been collected in the Pueblo Bonito ruin 25 years before by the Hyde expedition. Accordingly sections were cut from seven beams which this expedition had brought back to New York City. One of these sections was a cedar and has not yet been interpreted, but the others were immediately identified in age both among themselves and with reference to the Aztec timbers. It was found that these Pueblo Bonito beams were cut within a few years of each other at a time preceding the

cutting of the timbers at Aztec by 40 to 45 years. Many of the timbers of each ruin were living trees together for more than one hundred years and some even for two hundred years, and there seems no possible doubt of the relative age here determined. This result showing that a Chaco Canyon ruin was built nearly a half century before Aztec is the first actual determination of such a difference in exact years. A single beam from Peñasco, some 14 miles down the Chaco Canyon from Pueblo Bonito showed that its building was intermediate between Pueblo Bonito and Aztec.

Another association of growth rings with prehistoric deposits has rapidly developed in the last two years. In 1904 the writer discovered an Indian burial at a depth of eight feet in a cultivated field near Flagstaff, Arizona. A skeleton and two nests of pottery were revealed by a deep cut which a stream of water had made through the land. Near the burial was an ancient pine stump standing in place 16 feet underground. The tree was later discovered by a neighbor and became part of a bridge support. The Indian remains were given away except a red bowl of simple pattern and a good piece of black and white ware which is now in the Arizona State Museum. In 1920 the search for these buried trees was resumed and more than a half dozen in excellent preservation were found at depths from four to twelve feet. Mr. L. F. Brady of the Evans School gave most important help in getting out sections of these. In the summer of 1921 he again resumed the search and found several more buried trees and especially determined several levels at which pottery and other Indian remains are plentiful. These buried trees have been preserved by their pitch and show here and there quantities of beautiful little white needle-shaped crystals, which Dr. Guild has discovered to be a new mineral and to which he has given the name "Flagstaffite."

Several conclusions are already evident in the study of these buried trees. In the first place they supply much desired material from which some data regarding past climates may be obtained. The trees buried most deeply have very large rings and a certain kind of slow surging in ring size. Both of these features are characteristic of wet climates. The stumps at higher levels show characters common in dry climates, that is, general small rings and a certain snappy irregularity with frequent surprises as to size. This variation with depth gives a strong intimation of climatic change. The cycles dominant at these different levels also may be read from these sections and are likely to prove of great value.

In the second place this material will help in determining the age of the Indian remains and perhaps even of the valley filling in which these objects were located. There are several ways of

getting at this which will take time in working out but there is one inference immediately evident. One log was buried only eighteen inches, yet its rings do not tally with the 500 years of well determined rings of modern trees in that neighborhood. Allowing about a century for the sap-wood lost from the buried tree and a half century more necessary to detect cross-identity, we have an approximate minimum of 350 years for that foot and a half of depth. The age of Indian relics at four and even nine feet must be very considerable.

These then are the first results of the application of the general study of tree rings to archeological work and suggest further possibilities. Not only does it seem probable that this beginning of relative chronology of the wonderful ruins of the Southwest will be extended to include other ruins in this region, but this study of the prehistoric writing in trees will help in the clearer understanding of the climatic conditions which existed in those earlier times when the largest bona fide residences in the world were being built.

IX. Conclusion

The economic value of this study of tree rings and climate is to be found in the possibility of long-range weather forecasting. In non-economic terms we are trying to get the inter-relationships between certain solar and terrestrial activities by the aid of historical writing in the trees. The work is not done; a wide door is open to the future. Hence it is impossible to make an artistic conclusion. There is no real conclusion yet. Some definite results have been reached and they encourage us to hope for larger returns in the future. Through this open door we can see attractive objectives looming above us and we note the outlines of some of the hills to be surmounted. To climb these metaphorical hills we need groups of trees from all parts of this country, from numerous specially selected spots and areas, from distant lands; we need ancient tree records from Pueblo ruins and modern Hopi buildings, from mummy case and viking ship, from peat-bog and brown-coal mine, from asphalt bed and lava burial and from all ancient geologic trees in wood and stone and coal. We need measuring instruments, workers, museum room for filing and displaying specimens. And we need great quantities of climatic data obtained with special reference to tree comparison. With all this and with a spirit behind it, we shall quickly read the story that is in the forest and which is already coming to us through the alphabet of living trees.

VARIABILITY VS. UNIFORMITY IN THE TROPICS

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IT is commonly stated that tropical climates are extremely uniform. This is only partly true. They indeed have comparatively slight seasonal variations in temperature and in the length of day and night, and large areas have rather steady winds much of the time. But continual emphasis upon the uniformity of tropical climates is misleading because there are important variations in temperature and wind, while the rainfall of the lower latitudes appears to be more variable on the average than the rainfall of higher latitudes. There likewise appears to be more variation in storminess and in rapid change of air pressure than in higher latitudes.

Recent field investigations (financed by the Bishop Museum of Honolulu and Yale and Indiana Universities) in Hawaii, Fiji, tropical Australia, the East Indies, the Philippines and tropical China, and examination of official meteorological records concerning these areas and others have disclosed interesting evidences of tropical variability and have convinced me that the conventional statements, based on averages, are sufficiently misleading to make it worth while to emphasize the climatic variability occurring in the tropics.

The small seasonal contrasts in temperature which are characteristic of the tropics are perhaps the chief reason why the impression has been gained that tropical climates are uniform in other respects. Another reason for this common belief is the fact that the climatic data concerning the tropics are chiefly available in the form of averages. Averages by themselves are very misleading and should be supplemented as soon as possible by statements as to extremes, and as to normal extent of departure from means.

Although the average seasonal range in temperature is indeed small in low latitudes as compared with middle latitudes, there is an appreciable seasonal contrast in latitudes more than 10° or 15° from the equator. Indeed some parts of the tropics have about as great a seasonal range of temperature as certain especially uniform parts of higher latitudes. This is illustrated when the average

differences in mean temperature between the three warmest months and the three coolest of the following pairs of seaport cities are compared. Some of the cities in the right-hand column are not within the tropics according to the narrowest limitation of that zone. However, all are within the belt dominated by the Trades during most of the year, which is the belt commonly considered as tropical.

TABLE 1

SEASONAL RANGE OF TEMPERATURE

Calcutta,	range 18° F., vs.	Dublin,	range 17° F.,	22° N. vs. 53° N.
Hongkong,	range 20° F., vs.	Glasgow,	range 12° F.,	22° N. vs. 56° N.
Brisbane,	range 17° F., vs.	Hobart, Tas.	range 15° F.,	27° S vs. 43° S.
Durban,	range 11° F., vs.	Dunedin, N. Z.,	range 14° F.,	29° S. vs. 46° S.
Cairo,	range 16° F., vs.	Bergen, Nor.,	range 22° F.,	30° N. vs. 60° N.
New Orleans,	range 26° F., vs.	Vancouver,	range 22° F.,	30° N. vs. 49° N.
Madras,	range 9° F., vs.	San Francisco,	range 8° F.,	13° N. vs. 38° N.
Naples,	range 25° F., vs.	London,	range 22° F.,	41° N. vs. 51° N.

Even in regard to extremes of temperatures, some cities in fairly low latitudes have ranges which approach those of the less variable parts of the relatively high latitudes. This is illustrated by the following table showing the difference between the highest and lowest temperatures ever officially recorded at certain pairs of seaport cities up to a recent year.[1]

TABLE 2

EXTREME RANGE OF TEMPERATURE

Calcutta,	range 64° F., vs.	Dublin,	range 74° F.,	22° N. vs. 53° N.
Hongkong,	range 65° F., vs.	Glasgow,	range 78° F.,	22° N. vs. 56° N.
Bombay,	range 54° F., vs.	Lisbon,	range 62° F.,	19° N. vs. 40° N.
Madras,	range 55° F., vs.	San Francisco,	range 72° F.,	13° N. vs. 38° N.
Rio de Janeiro,	range 52° F., vs.	Wellington,	range 58° F.,	23° S. vs. 42° S.
Brisbane,	range 73° F., vs.	Hobart, Tas.,	range 78° F.,	27° S. vs. 43° S.
Durban,	range 71° F., vs.	Dunedin, N. Z.,	range 71° F.,	29° S. vs. 46° S.
Cairo,	range 82° F., vs.	Bergen, Nor.,	range 84° F.,	30° N. vs. 60° N.
New Orleans,	range 95° F., vs.	Sitka,	range 90° F.,	30° N. vs. 57° N.
Capetown,	range 68° F., vs.	Amsterdam,	range 86° F.,	34° N. vs. 52° N.

That there are appreciable seasonal contrasts in temperature in lower latitudes is not surprising when the seasonal variation in insolation is considered. In spite of the fact that the sun shines vertically somewhere between the two tropics every day in the year, there is a great change in angle of incidence. Few people realize that when the sun is vertically over the northern tropic

[1] References to sources of data are given in a longer, more technical article on "Variability of Tropical Climates" to be published in *The Geographical Journal* (London).

(Cancer), it shines upon the southern tropic (Capricorn) less nearly vertically by 4 degrees than upon the Arctic Circle. The latitude of New York receives much more heat from the sun on June 21 than does the equator, for not only is the sun six degrees more nearly vertical than at the equator, but moreover the days are almost four hours longer.

Although on the average tropical regions show less contrast in seasonal change of temperature than do middle latitudes, the reverse is true in respect to daily range. The night has been called the winter of the tropics. The daily range is considerable in all lower latitudes, although it is less in the more humid regions than in the more arid. On the average it is distinctly greater than the normal range in higher latitudes. This is due to two chief influences: Day and night are more nearly equal in length, and hence there is a closer balance between the duration of the heating and cooling periods than occurs in higher latitudes, where the nights are too short in summer for marked cooling and the days are too short in winter for effective heating. The other great cause is the higher average temperature, since the escape of heat varies as the fourth power of the absolute temperature. This means that normally there is much greater cooling per nocturnal hour wherever the day-time temperature is high than where it is low. A third reason why the diurnal range averages greater in low latitudes (below 30°) is that a larger proportion of the area is arid or semi-arid than is the case in middle latitudes.

In the tropics the nights often become so cool that considerable discomfort results. Even in an insular climate like that of Suva, Fiji (latitude 18°S.), in spite of the wind blowing off the sea, and a rainfall of over 100 inches fairly evenly distributed throughout the year, it commonly becomes so cool at night that the sensitive residents wear wraps if they walk out late in the evening. Indeed, even the heavy army overcoats are frequently worn with comfort at night and in the early morning during the cooler season. In drier parts of the tropics, the nights become much cooler than in a humid locality like Suva. On the dry western sides of the Fiji Islands, for example, temperatures below 40°F. have been recorded near latitude 16° close to sea level, and in dry continental areas frost is not unknown near sea level, as for example within 20° from the equator in Australia and Africa.

Another type of marked cooling in the tropics is the sudden drop, often as much as 6° or 8°F., which occurs in thunder-storms, which are very frequent in many parts of the tropics, far commoner on the average than in higher latitudes. Sometimes, as when hail falls in quantity, the temperature-drop is much greater.

Hail storms are not very rare in some tropical localities. For example, ten hail storms were reported in ten years in latitudes 13° to 16° S., near sea level in the Northern territory of Australia. Three hail storms occurred in Panama (latitude 9°) in a twelve year period.

Cold snaps of still other types occur within the tropics. For instance, cold winds sometimes sweep down from higher latitudes and bring low temperatures surprisingly near the equator. Zero temperatures have been officially recorded in subtropical Northern Florida (lat. 30° N.), and a temperature of only 10° above zero F. has occurred on the Gulf Coast of Mexico in latitude 25½° N. Central coastal Queensland is subject to "severe frosts" during four months in the year within 21° of the equator, while freezing temperatures have occurred even in the day time in southeastern Asia in latitude 22° at sea level. Still farther south, on the China Sea near Manila, latitude 15°, for example, northerly gales in winter occasionally make overcoats welcome even in the day time. Similar cold snaps occur in the cooler months in other tropical localities such as the Hawaiian Islands, Jamaica and Fiji. Indeed, remarkable as it may seem, the Weather Bureau reports a snow flurry practically at sea level at Mahukona, Hawaii (lat. 20° 11′), lasting ten minutes on December 29, 1921. Perhaps even more surprising is the great cooling reported as not rare in winter on the coast of Venezuela, in latitude 10° N. Director Ugueto, of the Cajigal Observatory, announces that gales from the north off the sea occasionally bring temperatures of 45° F. or even less, in the day time, lasting a number of days. They are not associated with thunderstorms, for the sky is clear at the time.

Because of the sensitiveness of the residents of the tropics to low temperatures, chills and colds often develop and sometimes pneumonia. Many observers have been impressed by the abundance of coughs and catarrh in the tropics. They may be more common there than in Canada. Indeed there is considerable truth in the saying that "cold causes more suffering in the tropics than in polar or subpolar regions."

Now as to the winds: Five chief sorts of variation within the tropics merit attention: (1.) Even when the direction is fairly constant, there is a marked diurnal variation in velocity. Calm nights are the rule in trade wind deserts and nearly calm nights are common elsewhere on the land except upon exposed elevations. Likewise at sea, while the diurnal range is less than on land, it is notable. For example, Tetens reports a diurnal range of over 50 per cent. in the velocity of the wind at Samoa. In higher latitudes, while the wind frequently dies down at nightfall, and normally

weakens, windy nights are by no means uncommon, and very frequently the wind is stronger by night than by day. In the tropics, windy nights occur on lowlands only during the passage of rather rare severe cyclonic storms. Moreover, disturbances of an intensity which would give strong nocturnal winds in middle and high latitudes cause only moderate winds at night at low elevations in the tropics. This is due to the influence of the comparatively great decrease in vertical convection at night in low latitudes caused by the greater cooling of the surface air than of the overlying free air. It is for this reason also that even relatively steep barometric gradients in monsoonal regions permit a marked dying down of the surface winds at night.

(2.) Seasonal as well as diurnal variations in the velocity of the trades are common. "Half Gales" are characteristic of Fiji, the New Hebrides and many other South Pacific groups in their spring months, and even "whole gales" are frequent during the northeast "monsoons" in the China Sea during winter. On the other hand, in other months calms or light breezes are the rule when the doldrums migrate past, as they do twice each year with the seasonal change in the altitude of the sun. Along the margins of the tropics calms likewise occur when the extra-tropical belt of high pressure migrates equator-ward in the cooler season.

(3.) There is a radical seasonal change in the direction of the Trades when they cross the equator; those crossing from the north change from east-northeast winds to northwest, due to the deflective effects of the earth's rotation. Consequently many places near the equator have easterly winds much of the year; calms while the doldrums are migrating past, and westerly winds when the doldrums are situated in higher latitudes on their side of the equator. Then, as the sun returns equator-ward, calms and easterlies recur.

(4.) Another evidence of tropical variability is that land and sea breezes are more characteristic of the lower latitudes than of the higher. This is because the contrast in the temperature of land and water averages greater in low latitudes. Indeed while in middle and high latitudes sea breezes are rare except during the hottest weeks, in many parts of the lower latitudes they occur almost every day in the year, and give a wind régime which is very different from the constant easterly trades supposedly characteristic of the tropics. The monsoons are a special type of land and sea breezes, since they blow towards the land for many consecutive weeks during summer, and in the opposite direction in winter. While produced by temperature contrasts of extra-tropical regions, the monsoons are most strongly felt in tropical latitudes (below

30°) and give large and important regions a sharp seasonal contrast in wind directions. Between the winter and the summer monsoons, there commonly is a spell some weeks in length when the winds are irregular and often light. After they become steady in direction they often fluctuate notably in velocity from day to day as well as between day and night.

(5.) Although winds due to cyclonic disturbances do not occur so frequently within the tropics as in higher latitudes, they are significant. The "boxing of the compass," during which the wind comes from every direction in turn, occurs many times a year in most parts of the tropics, while occasionally cyclonic gales or even violent hurricanes occur. Official Japanese daily weather maps and annual summaries of storm tracks show an average of over fifty tropical cyclonic disturbances a year in east longitudes 115°-145°, while a study of the Australian daily weather maps for 20 years shows an average of over 30 a year in similar longitudes south of the equator. Thus in less than one seventh of the circumference of the earth there are over 80 cyclonic disturbances in an average year. This is, however, the stormiest sector.

Mention should be made of thunder squalls which are, on the average, more violent in low latitudes than in higher latitudes and more frequent. In addition, several regions in subtropical latitudes experience tornadoes or similar storms. Thus it is evident that there is considerable variation in respect to winds in the tropics.

Variations in rainfall have perhaps even greater significance than variations in temperature or wind. The indications are that in respect to dependability of precipitation, the lower latitudes are notably less fortunate than are middle latitudes. In order to compare the variability of rainfall in the tropical half of the globe with that of the higher latitudes, I have inspected the official records for many cities in both zones. The selection was impartial, being determined solely by whether or not the data were available. The comparison is between the greatest and least annual precipitation officially recorded before a recent year. The length of the record varies, but in general it is shorter in low than in higher latitudes and hence tends to lessen the apparent range in lower latitudes. Tables 3 and 4 give the figures to the nearest one tenth of an inch. It will be noticed that the maximum amount of rainfall received in a year was less than twice the minimum for Chicago, Christiania, Edinburgh, Ottawa, Paris, Pekin and Tokio, and only a trifle more than twice the minimum in the case of Amsterdam, Berlin, Berne, London, New York, Petrograd, St. Louis, Vienna and Wellington, N. Z. Very few middle or high latitude cities appear to have ex-

perienced three times as much precipitation in their wettest year as in their driest. Madrid, Washington, D. C., and Vladivostock are exceptions as are some cities in southern Europe, while Hobart, Tasmania, Buenos Aires, Rome and San Francisco are notable for having received about four times as much. However, many geographers class Buenos Aires, Rome and San Francisco as subtropical. Furthermore, Madrid and Vladivostock have an average rainfall of less than 20 inches, and thus are more subject to large percentage changes than is the case where the normal rainfall is larger.

TABLE 3

EXTREME ANNUAL RANGE IN RAINFALL IN MID-LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Amsterdam	52° N.	27 3 in.	17 6 in.	40 6 in.
Berlin	52° N	23.0	14.3	30 0
Berne	47° N.	36.3	24 7	58 2
Buenos Aires	35° S	36.8	21.5	80.7
Chicago	42° N.	33.5	24 5	45.9
Christiania	60° N.	22.5	16.3	31.7
Edinburgh	56° N.	25.2	16.4	32.1
Hobart	43° S.	23.7	13.4	43.4
London	51° N.	24.0	18 2	38 2
Madrid	40° N.	16.2	9.1	27.5
New York	41° N	42.5	28 8	59.7
Ottawa	45° N.	33.4	26.4	44.4
Paris	49° N.	21.9	16.4	29.6
Pekin	40° N.	24.4	18.0	36 0
Petrograd	60° N	21.3	13.8	29.5
Rome	42° N	32.6	12.7	57.9
San Francisco	38° N.	22.8	9.3	38.8
St. Louis	39° N.	37.4	23.4	49.2
Tokio	36° N.	59.2	45.7	77.1
Vladivostock	43° N.	19.5	9 4	33 6
Vienna	48° N.	24.5	16.5	33.9
Washington	39° N.	43.8	18.8	61.0
Wellington, N. Z.	42° S.	49 7	30.0	67.7

Turning now to the lower latitudes: Among 20 scattered cities selected impartially, in no case was the officially recorded rainfall of the wettest year less than twice that of the driest. Only in Calcutta and Caracas did the ratio fall as low as 2¼. In Johannesburg it was 2½ times as great, and in Durban, Hongkong and New Orleans it was 2¾. In Colombo and Honolulu it was about 3; in Bombay, Buenos Aires and Manila each about 3½; in Madras 4½; in Brisbane and Singapore 5; and in Rio de Janeiro 13.4. All these cities have a normal rainfall of 30 inches or over, and the mean for the group of cities is 55.6 inches in contrast with a mean of

30.5 inches for the cities of Table 3. Since percentage fluctuations tend to become smaller as the total rainfall increases, the great fluctuations experienced by these tropical cities are all the more notable.

TABLE 4

EXTREME ANNUAL RANGE IN RAINFALL IN LOW LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Bombay	19° N.	71.1 in.	33.4 in	114.9 in.
Brisbane	27° S.	45.6	16.2	88.3
Calcutta	22° N.	62.0	39.4	89.3
Caracas	11° N.	30.0	23.7	47.4
Colombo	7° N.	83.8	51.6	139.7
Durban	29° S.	40.8	27.2	71.3
Hongkong	22° N.	84.1	45.8	119.7
Honolulu	21° N.	31.3	14.6	45.0
Johannesburg	26° S.	31 6	21.7	50.0
Madras	13° N	49.0	18.5	88.4
Manila	15° N.	76.3	35.7	117.0
Naples	41° N.	34.0	21.7	56.6
New Orleans	30° N.	55.7	31.1	85.7
Rio de Janeiro	23° S.	46.8	4.7	63.5
Singapore	1° N.	92.0	32.7	158.7

If tropical and subtropical cities having an average rainfall of less than 20 inches are included in the comparison, even more violent ranges are disclosed. For example, Cairo, Egypt and San Diego, Calif., each received about 6⅓ times as much rainfall in their wettest year as in their driest; Athens 7 times; Helwan, Egypt, 18 times; and Onslow, W. Australia, 47 times as great.

None of the cities of Table 4, except Singapore, happens to be close to the equator, the necessary data for other equatorial cities not being readily available. However, extreme fluctuations occur almost under the equator even on oceanic islands. At Malden Island (lat. 4° 1′ S.; long. 154° 58′ W.), for example, the annual totals of rainfall have varied from 3.95 inches in 1908 to 63.41 inches in 1905. At Oceanic Island (lat. 0° 52′ S.; long. 169° 35′ E.), nearly 2,000 miles west of Malden Island and within a degree of the equator, the range has been between 19.61 inches in 1909 and 158.93 in 1905 (141.12 in 1911). There was likewise a range of from 74 rainy days in 1910 to 232 in 1911. Upon the Hawaiian Islands, Puuhela, on Maui, (lat. 20¾° N.; long. 156½ W.) received only 2.46 inches of rain in 1912, but received 33.14 inches in 1918. Many other Hawaiian stations show a somewhat similar range, and the rainfall of the group as a whole is characterized by the government meteorologist as "extremely unreliable."

The great variability illustrated by these three mid-Pacific Islands is the more notable because insular climates are commonly

thought to be exceptionally uniform, particularly if near the equator and not dominated by near-by continental masses, nor within hurricane regions. None of these three is in a hurricane region, all are far from land and two are close to the equator.

So many other regions in low latitudes experience an undependable rainfall that it seems unnecessary to more than mention the famines produced by droughts in India and in southern China, or the destructive floods in the same countries. Tropical Australia has perhaps even worse droughts and floods and is saved from terrible famines only by the sparseness of the population and the skill used in reducing the losses to a minimum. The annual variation at Onslow in tropical West Australia, for instance, was from 0.57 inches in 1912 to 26.96 in 1900, and the average variability from year to year in that region has been about 50 per cent. of the average rainfall.

Excessive falls in short periods afford other illustrations of the uncertainty of rainfall. In tropical Australia, on more than 400 days in a 25-year period more than 10 inches of rain fell in 24 hours according to official records, while in temperate Australia there have been very few recorded instances of such heavy rainfalls—none in Victoria or South Australia and only two in Tasmania (Max. of 18.1 inches in three days). In tropical Australia, more than 20 inches has been officially recorded as falling in 24 hours on 42 different days, and more than 30 inches on four occasions. The maximum was 35.71 inches at Crohamhurst, Queensland, Feb. 2, 1893. However, 60 inches fell in three consecutive days at Mt. Molloy, Queensland, and there have been many 48-hour periods when more than 25 inches fell.

At Suva, Fiji, it frequently happens that more than 10 inches of rain falls within 24 hours; there were 4 cases in the 7-year period 1906-12. The maximum has been 26.5 inches in less than four hours on August 8, 1906.

What is believed to be the world's record for officially measured rainfall in 24 consecutive hours occurred near Manila on Feb. 14-15, 1911 (1,168 mm., 46 inches). The other stations at which this maximum has been approached are also in low latitudes, namely, Cherrapunji, India, June 14, 1876, 40.8 inches; Silver Hill, Jamaica, 57.5 inches in 48 hours; Funkiko, Formosa, 40.7 inches on Aug. 31, 1911, and at Hononu, Hawaii, 31.9 inches, Feb. 20, 1918.

With such sharp annual and daily extremes as these, it is reasonable to expect great monthly extremes. At Malden Island, mentioned above, for example, the range in officially recorded rainfall from 1890 to 1918 was as follows:

TABLE 5

MONTHLY VARIATION IN RAINFALL AT MALDEN ISLAND

January	from	0.00 in.	to	19.48 in.
February	from	0 00 in.	to	9.27 in.
March	from	0.15 in.	to	25.65 in.
April	from	0.47 in.	to	12 34 in.
May	from	0.29 in.	to	12.30 in.
June	from	0.00 in.	to	12.49 in.
July	from	0.59 in.	to	10.10 in.
August	from	0.18 in.	to	5.56 in.
September	from	0.05 in.	to	3.03 in.
October	from	0.00 in.	to	5.27 in.
November	from	0.00 in.	to	8.72 in.
December	from	0.00 in.	to	8.20 in.

The four months, November, 1891, to February, 1892, received a total of only 0.72 inches, while the four months, January to April, 1915, received over 60 inches. The number of rainy days per year varied from 30 to 144.

At Oceanic Island, likewise, the monthly ranges are extreme. Within a nine-year period, February, March, April and November have each received 0.1 inches or less and also 21.3 inches, 28.9, 27.6 and 15.5 inches, respectively, and falls of 0.7 inches or less in May, August, September, October and December are to be contrasted with falls of from 12 to 19 inches received in other years in those same months.

The Philippines show scarcely less violent extremes. In the 16-year period, 1903-18, 42 of the 70 stations had a total of about 160 months with no rainfall, while the wettest months at about half the stations exceeded 40 inches of rain, and had less than 20 inches in the case of only 8 stations. This variation is only partly seasonal, for a month which is very dry one year may be excessively wet another. Severe and widespread droughts, with over 100 days without rain, are contrasted with destructive floods caused by rainfalls of more than 20 inches in a day or two.

Even at Hilo, on the wet side of Hawaii, where the rainfall averages 139.4 inches a year and is relatively dependable, a 13-year period shows that the monthly amounts have varied widely, January from 0.5 inches to 38.6, February from 1.9 to 32.5 inches, March 2.9 to 45.4, April 3.7 to 25.1, and December from 1.7 to 27.8 inches, for example.

That the great variation from year to year in rainfall discussed in the foregoing pages is not local is suggested by various data. For example, the average rainfall of the entire Hawaiian group (150 stations) was more than twice as great in 1919 as in 1918 (112.9 in. vs. 54.5 in.). Likewise in the Philippines during the droughts such as that referred to in a preceding paragraph, nearly all of the 70 stations are affected similarly.

Another type of variation in rainfall which is prominent in the tropics is the seasonal. Very few tropical localities receive their rainfall as evenly distributed throughout the year as is common in many parts of middle latitudes. Distinct wet and dry seasons are the rule. The rainy summers and dry winters of India and China are well known. Most of tropical Australia also receives almost no rain for six months and from 15 to 50 inches or more in the other six months. Hawaii and many other places near the margins of the tropics receive much of their rainfall in winter, while still other parts of the tropics have two wet and two dry seasons.

In order to compare the monthly variability of rainfall in low and middle latitudes, a planimeter measurement was made of Supan's map of Percentage Range of Mean Monthly Rainfall in Bartholomew's Atlas of Meteorology. This map shows four types of regions: (1) where the wettest month is less than 10 per cent. rainier than the driest month, (2) where the wettest month is from 10-20 per cent. rainier than the driest; (3) where the range is from 20-30 per cent, and (4) where it is over 30 per cent. Tables 6 and 7 show the approximate area and the percentage of each type by continents. Table 6 concerns middle latitudes (30° to 60°); Table 7 concerns low latitudes (30° N. to 30° S.).

TABLE 6

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° TO 60°

	Range less than 10 per cent		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mi	%	Mil. Sq. Mi.	%
Europe	1.77	65	.88	34	.03	1	0	0
North America	2.06	43	2.62	54	.14	3	0	0*
South America	.23	26	.55	60	.13	14	0	0
Asia	.22	3	2.65	34	3.75	49	1 13	14
Africa	.05	15	.23	44	.47	41	0	0
Australia	.36	47	.40	53	.005	.6	0	0
Total and Means	4.70	26	7.34	42	4 42	25	1.13	7

TABLE 7

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° N. TO 30° S.

	Range less than 10 per cent.		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq. Mi	%	Mil. Sq. Mi.	%	Mil. Sq. Mil.	%	Mil. Sq. Mi.	%
North America	0	0	.46	39	.70	61	0	0
South America	.12	2	4.91	76	1.31	21	.04	1
Asia	.10	2	.96	23	2.56	60	.63	15
Africa	0	0	2 28	20	8.86	78	.21	2
Australia	.16	7	.63	28	1.32	59	.13	6
East Indies	.43	36	.72	63	.01	1	0	0
Total and Means	.81	3	9.76	38	14.76	55	1.01	4

It will be seen that low latitudes have over three times as large an area possessing a monthly variability of over 20 per cent. as is the case in mid-latitudes and twice as large a percentage of their total area has this range. The one large area in mid-latitudes having the fourth, the most extreme, type of rainfall variability is the Tibetan Plateau, which has little agricultural value because of its great altitude. Furthermore, the month of least precipitation in mid-latitudes commonly is in the winter when plants require little moisture while the wettest month usually is in summer. On the other hand, the driest month of the tropics is also a hot month, with active evaporation. This unfortunate combination is very hard on plants, and is the reason for the lack of forests in many places having a large annual rainfall. For instance, parts of tropical Australia having over 60 inches of rain a year possess no real forest because several months are extremely dry and hot.

In respect to the more uniform rainfall type, where the range between the driest and wettest month is less than ten per cent. mid-latitudes have nearly six times as large an area as low latitudes. This type comprises about 26 per cent. of the total land area of mid-laditudes while it makes up only 3 per cent. of low latitudes. Other interesting comparisons come out on further study of these tables.

Why should the lack of marked seasons in respect to temperature be emphasized and the presence of marked seasons of rainfall be largely ignored by most writers on the tropics?

Another climatic factor subject to marked changes is storminess. Cyclonic storms are erratic in all parts of the world but the extremes appear to be greatest in low latitudes. The range in the number of hurricanes damaging Australia, for example, has been from one hurricane in 1907 and 1919 to seven in 1916 and eleven in 1912. In Fiji some years have none, but several years have had three each and one year four. In the South Indian Ocean the variation reported by the Mauritius Observatory has been from one storm in 1900 to eight in 1894 (and several other years) and to thirteen in 1913. In the Philippines in a 15-year period the number of very severe typhoons varied from one in 1916 to seven each in 1908 and 1911. In respect to less violent cyclonic storms there appears to be a somewhat similar range. For example, the total number of well-marked tropical cyclones occurring in Queensland, Australia, varied from eight in 1920 to 24 in 1916. In respect to the month of occurrence, as well as in annual frequency, there likewise is marked irregularity. In some years cyclones may be lacking during the months when they normally are most frequent and occur only in months supposed to be

free from dangerous storms. Of thunder storms also there is marked variation, perhaps more than in higher latitudes. Many stations in Fiji and elsewhere have experienced several times as many in one year as in another. While many hurricanes are accompanied by appalling lightning, other equally severe hurricanes have none.

Slight changes of weather are almost constantly taking place in the tropics. A rainy spell will be succeeded by a less rainy one or by a few rainless days; a hot spell by a slightly cooler one; a spell of fitful breezes, by several days of steady winds. Such changes have been noticed by the writer in Jamaica, Hawaii, the Philippines, the East Indies, Queensland and elsewhere, but have been especially studied in Fiji. There, a study of the official records taken at Suva reveals an average of about 20 distinct spells of weather well distributed throughout the year, with about as many less distinct changes.

In conclusion, when all these types of variation occur, is it right to give the impression that tropical climates are extremely uniform? But although tropical climates are not so uniform as has been supposed, it does not follow that they are better adapted to civilized man than has been supposed. Most of the variability within the tropics is of a highly irregular sort compared with the variability characteristic of the parts of the higher latitudes where civilized man mostly lives. Indeed it appears that tropical climates are unfavorable for a high type of civilization not alone because of the high temperatures and the general lack of stimulating seasonal changes in temperatures, but also because of the often extreme undependability of the rainfall, the occurrence not infrequently of destructive windstorms and other unfavorable variations. But, nevertheless, highly civilized man can cope with the numerous problems of the tropics far better than can primitive people. Indeed, the latter, unaided, have made little progress. Hence fuller utilization of the tropical resources awaits a greater participation by civilized man.

THE POSSIBILITIES OF EXTERMINATING INSECTS

By Dr. E. P. FELT
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THIS is a special phase of the war against insects, the general aspects of which have been discussed in such an illuminating and very suggestive manner by Dr. L. O. Howard, chief of the Federal Bureau of Entomology, in his address as retiring president of the American Association for the Advancement of Science.[1] Dr. Howard has given in this account a most excellent summary of the broader phases of insect control, though, for some reason, possibly because he knew of the writer's interest therein, he refrained from discussing exterminative measures or the possibilities of eradicating isolated infestations.

This is something of considerable practical importance on account of the fact that more than half of our most injurious insect pests have been introduced from abroad and the process is still going on in spite of the widespread and, as a whole, well directed Horticultural Inspection Service of the general government and the various states. This latter work has undoubtedly prevented the establishment of a number of injurious insects and delayed the introduction of others, though occasionally we find a destructive pest well established in a section and in the ordinary course of events destined to extend its range and possibly inflict very serious losses over a considerable period of years.

The Gipsy Moth, the Brown-Tail Moth, the Elm Leaf Beetle, the Leopard Moth and the recently introduced Japanese Beetle are somewhat familiar examples in the eastern United States, while the south has become altogether too familiar with the Boll Weevil, the Pink Boll Worm and very lately the Mexican Bean Beetle. There is, in addition, the recently introduced European Corn Borer, now beyond any possibility of extermination so far as this hemisphere is concerned, though at one time it must have been within possibilities. We are also confronted in the early history of the Gipsy Moth with the futile attempt of the state of Massachusetts to exterminate the insect, while later developments dem-

[1] (a) "On Some Presidential Addresses"; (b) "The War against Insects." *Science*, 54: 641-651, 1921.

onstrated beyond question the practicability of accomplishing what at one time appeared to many as an unattainable ideal.

It must be conceded at the outset that problems of this nature are surrounded by manifold difficulties and that, within certain limits, each case must be decided upon its merits. In the first place, it is exceedingly difficult to determine the future status of an insect before it has become well established and thus presumably ineradicable, unless some unusual limitation makes extermination relatively easy. Granting that there is substantial agreement among scientific men as to the desirability of exterminating a given species, the great problem of educating the public to view the matter from the right standpoint and thus make possible the securing of means to prosecute a vigorous campaign still remains to be solved. Furthermore, initial operations, if the undertaking is to be successful and conducted in the most economical manner, must ordinarily be started before successful measures have been thoroughly demonstrated. There is always an element of doubt in regard to the possibility of serious injury, the feasibility of extermination and the methods to be employed, consequently it is not easy to secure a combination which will bring about the desired results. On the other hand, there is practical agreement among most scientific men familiar with the work of insects to the effect that extermination, when possible, is immensely cheaper and more desirable than the prosecution of more or less unsatisfactory control measures in a constantly expanding infested territory.

Earlier attempts to exterminate insects were based largely on some plan designed to catch or kill the last remaining insect, preferably within a year or two and certainly within a few years. Some have even advocated reducing the infested territory to practically desert conditions in such a manner as to make all insect life at least impossible. This latter is undoubtedly possible in the case of very restricted infestations and may be justified if the insect is an exceedingly destructive or dangerous one. It is out of the question if an extended area is infested or the insect one which is not particularly dangerous to life and does not threaten a basic crop or industry. Most cases come in this latter category and therefore do not justify extreme or drastic measures.

It seems to the writer that the method of progressive reduction, if one may use a special term, has not received the consideration it deserves, and yet it has been the method which has brought about extermination of Gipsy Moth colonies in areas well removed from the generally infested territory. The plan in such a case was to bring about conditions unfavorable for the multiplication of the insect and, by following up the matter from year to year,

eventually reduce the numbers of the pest so greatly that natural agents or hazards actually bring about extermination. It is interesting in this connection to review the work of the earlier days against the Gipsy Moth when a systematic and very costly effort was made to find every egg mass in woodlands as well as on improved grounds and destroy them by hand, trees being climbed and walls taken down and relaid in the search for the last egg mass. This was supplemented by spraying the foliage in the infested area and banding the trees for caterpillars. Later developments have shown that much of this laborious egg hunting can be eliminated by a system of spraying and cutting out low bushes or favored food plants. Conditions are thus changed to such an extent that the insect is unable to maintain itself and eventually disappears.

Apparently, because insects are small and under certain conditions exceedingly abundant, we have failed to make allowance for the results following a great reduction in the number of individuals, especially if this be continued year after year. The matter is of more than passing importance, because there is a possibility of making practical application of the principles involved and obtaining at a relatively moderate cost results which might eventuate in large savings by eradicating injurious species before they had an opportunity of establishing themselves over extended areas.

It may be held that the Gipsy Moth is in a class by itself and to a certain extent this is true. Nevertheless, until this method has been widely tested with a variety of insects, no one is in a position to state that it is impracticable. Even a casual study of injurious insects shows marked local variations in abundance. These must be due to some cause, and in many instances they are directly associated with agricultural practices or differences in natural conditions. The detection of such unfavorable conditions and the bringing about of similar modifications in areas where insects are destructive, is one of the opportunities of the economic entomologist and, as stated above, there is a probability of the same principle being applied successfully to the extermination of recently introduced injurious insects, provided the infested area is not too large. This last is not necessarily an insuperable difficulty. It may simply mean a better organization and an extension of operations over a longer period of time.

If we turn from the field of entomology to the broader realm of zoology, and consider what has occurred in the case of larger forms, we may find some very suggestive hints. It should be noted in this connection that in not a few instances the apparently impossible has been brought about by the irresponsible urge of self interest and not through carefully directed cooperative efforts for the attainment of a definite aim.

One of the most striking instances of this kind is the extermination of the Passenger Pigeon, a bird at one time so extremely abundant that three carloads a day were shipped from one small Michigan town for a period of forty days. The Great Auk, the Labrador Duck and the Pallas Cormorant have passed into history. The Whooping Crane, the Trumpeter Swan, the American Flamingo, the Heath Hen and Sage Grouse are representative of a series of valuable and interesting birds doomed, in the opinion of Dr. Hornaday, to early extermination.

Large herds of Buffalo were saved from extinction at the last moment through the intervention of naturalists interested in preserving the wild life of the country. The Prong-Horned Antelope, the Big-Horn Sheep, the Mountain Goat and the Elks are traveling the same path as the Buffalo.

The depleted salmon, shad and herring fisheries, the necessity of protecting both the oyster and the lobster and the great scarcity of certain whales have been brought about by artificial agencies, though it would seem as if inhabitants of the water would have a better chance for escape from a persistent human enemy than would be the case with terrestrial forms.

It is true that these unfortunate conditions have resulted through specific peculiarities or limitations which made attack at certain points particularly effective, such as killing birds when migrating or in their nesting retreats or the wholesale catching of spawning salmon. Those dependent in large measure for their living upon some of these forms could not believe that the natural prolificacy of the species would not offset almost any levy by human or other agents. Are we not unconsciously assuming that because insects are apparently innumerable, systematic general measures continued over a series of years are foredoomed to failure? It by no means follows that immense numbers indicate impossibility of control or extermination.

The stimulus of a deadly peril is sometimes necessary to demonstrate the practicable. This has occurred in the case of yellow fever and, while the insect carrier was not exterminated, it was soon found entirely possible to greatly reduce the breeding of the "day mosquito" and by a combination of mosquito control measures and preventing insects from gaining access to infection, the disease was actually eradicated. The deadly peril of plague on the Pacific Slope drove home the lesson that safety lay in rat eradication and that this latter could be accomplished only by a simultaneous attack upon the rat, its food supply and habitations. This was carried to the extent of exterminating rats over considerable city areas. Given adequate incentive, there appears to be no prac-

tical reason why rat extermination could not be extended to entire cities or smaller communities through systematic repressive measures extending over a series of years. In this connection, it may be permissible to allude to the so-called Rodier method of rabbit and rat control, which depends simply upon systematic trapping and destruction of the females and the liberation of the males, since an excess of the latter, it is claimed, results in extermination or near extermination due to persistent persecution by the males of the constantly decreasing number of females. It is based on the utilization of well-known habits to bring about self destruction of the species.

The studies of bark beetles by Dr. Hopkins have shown the possibility of securing very efficient control by simply reducing their numbers, in some instances by 75 per cent., to such an extent that those remaining would be unable to overcome the natural resistance of the tree. This applies to enemies of living trees and presupposes that a minimum amount of injury must be inflicted or the attack can be successfully resisted. Were there sufficient incentive, it might be possible to go further with certain of these insects and bring about local extermination.

A concrete application along these lines is found in the attempt of recent years by the United States Biological Survey to destroy predatory animals such as wolves and coyotes and thus eliminate in large measure the very heavy losses of western stock growers. The work is organized on a cooperative basis with states and local associations and as a consequence losses have been practically ended over great areas of the most valuable summer and winter sheep ranges and reduced in others to very small amounts compared with earlier years. The practical value of such work is evidenced by the fact that interested states, in order to cooperate with the government, appropriated over $200,000.00 for the fiscal year of 1922, in addition to increased contributions by stockmen as individuals and through their organizations. Already areas have been cleared or partly cleared of the pests and it would seem from the progress made entirely possible to exterminate the most destructive of these animals throughout the more important stock-raising areas at least, and this through the well directed efforts of a relatively small number of individuals.

The systematic destruction of prairie dogs has resulted in over four million acres of public lands being "largely freed" from these pests. There has also been very effective work against pocket gophers and rabbits. It is within possibilities to make local and almost complete eradication absolute and thus in the course of years free large areas from serious pests.

The work of W. F. Fiske upon the Tsetse Fly has shown that it is only necessary to reduce the infestation by this pest to moderate limits in order to secure a very satisfactory degree of freedom from the deadly sleeping sickness. The studies of Roubaud upon malaria in France indicate an intimate connection between this infection and the number of mosquitoes per host. The author suggests what he calls animal prophylaxis, that is, the importation of enough cattle in certain areas to attract the insects and thus protect man to a large extent. The keeping of rabbits has been advocated more recently as a protection from malaria, and may be regarded as a variant of Roubaud's plan. All are forms of percentage reduction, a step which under certain conditions might be continued to the vanishing point, at least, so far as the infection is concerned.

Turning to the Acarina, we note the progressive extermination of the Cattle Tick from nearly 500,000 square miles of territory, and the consequent elimination from this area of a very serious infection. It was apparently an impossible undertaking until the decisive factors were ascertained. In this connection, it might be stated that gratifying progress has been made in demonstrating methods of controlling the Rocky Mountain spotted fever tick, a carrier of a deadly human infection. Even now plans are in progress to test the possibility of actually exterminating warble flies from large areas. This is somewhat different from the tick proposition. It appears to be within possibilities and is certainly worth a thorough test.

The history of the larger animals shows a number of cases of extermination or near extermination as a result of continued adverse conditions, and in historic times this has been due mostly to systematic hunting or fishing, and usually it has been confined to a restricted portion of the range, though in some instances it occurred at a period which would permit the maximum reduction in the species, namely, just before the breeding season.

The mere fact that a species occurs in immense numbers does not make extermination impossible, though it may greatly prolong the period during which adverse influences must operate.

It is evident from a study of insects and an examination of the factors resulting in the extermination of larger animals, that relatively minor changes in environment or well organized attacks limited to relatively few individuals or to comparatively restricted areas, may accomplish the apparently impossible.

It is also evident that the elimination of a certain residuum may safely be left to the operation of various natural causes. This latter is an extremely important factor in any attempt to exterminate

insects, since it is usually impossible to destroy the last individual or to bring about conditions over an infested area of some extent which would make the existence of insect life impossible.

In view of the above, we believe that the problem of insect extermination should receive most careful consideration and as opportunity offers, tests or demonstrations should be undertaken in order to obtain more trustworthy data relative to possibilities in this line of repressive work.

CITY PARKS AND PLAYGROUNDS AS HEALTH AGENTS

By Dr. JAMES M. ANDERS
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THE necessity for providing sufficient city parks and play spaces, including parkways and garden-streets, has been long appreciated by students of municipal sanitation and the truly enlightened part of the general public. We owe the existence of organized bodies for the purpose of promoting these agencies, all of which have been founded within the last half century, to a few leaders in the matter of community health and welfare and in civic advancement. As the result of their well-directed efforts considerable progress has been made in the important direction of providing an adequate proportion of open spaces in relation to the density and aggregate of municipal populations. Efforts to arouse public sentiment upon this vitally important question, however, should have received far greater encouragement than they did in the past.

In this connection it should be recollected that in consequence of the free immigration of inferior races our national physique has shown up to now a slow and gradual retrogression. It is high time that an intelligent, concerted effort be made with the avowed purpose of arresting this physical decadence and, more than this, of beginning a new advance. To the student of hygienic and sanitary principles the sources of bodily and moral efficiency are not obscure, and with the aid of sufficient popular support he can indicate the remedies for the cure of the existing state of things with reference to our physical deficiencies.

It will not prove difficult to show the connection of city parks and playgrounds with racial progress due to improvement in the national physique. Indeed, it is not too much to claim that a just appreciation of the beneficial effects of these breathing and play spaces of our cities would speedily lead to the acquisition of new areas and the development of land owned by cities for park and play purposes; this would mean a distinct advance in city building with reference to such questions as the number of houses to the acre, their proper grouping, and the extent of open spaces between units, as well as in street tree planting, all of which questions

affect the health and strength of the community, as will be clear hereafter.

The thirtieth annual report of the City Parks Association of Philadelphia sets forth the rôle played by the United States Government in physical demonstration of town planning on a large scale carried into execution in several localities, notably Yorkship, Portsmouth, N. H., and Wilmington, Del., during the recent war. Here was established a standard for city planning that it would have required a much longer period of time—quite a generation at least—to attain to in peace times. Attention should be directed to such government regulations as building ten to twenty feet back of the street line, fewer houses to the block and open space between adjoining houses, sixteen feet being the minimum. It is to be hoped that this example set by the government will not be lost, but will serve to inaugurate an era of decided progress in city building throughout our broad land. It is the duty of public-spirited citizens to see to it that modern town plans be adopted in connection with the future building of towns or settlements. True it is that out of appropriate town planning, as necessary sequences, grow hygienic and moral conditions which possess far-reaching influences for good. In other words, if our great American cities were models of city planning the effect would be not only greatly to increase real estate values, but also and more importantly to advance the essentials of human health and happiness. Confirmation of this statement is to be found in an article by Andrew Wright Crawford on "War Suburbs and War Cities," in which he quotes from a book by Charles Cadbury, Jr., the figures appended; they show the effect on children of the Garden Suburbs of Bournville, England, as compared with a ward in Birmingham, only twenty minutes away:

WEIGHT	Lbs. years, Age 6	Lbs. years, Age 8	Lbs. years, Age 10	Lbs. years, Age 12
Boys, Bournville	45.0	52.9	61.6	71.8
Boys, St. Bartholomew's Ward, Birmingham	39.0	47.8	56.1	63.2
Girls, Bournville	43.5	50.3	62.1	74.7
Girls, St. Bartholomew's Ward	39.4	45.6	53.9	65.7
HEIGHT	Inches	Inches	Inches	Inches
Boys, Bournville	44 1	48.3	51.9	54.8
Boys, St. Bartholomew's Ward	41.9	46 2	49.6	52.3
Girls, Bournville	44.2	48.6	52.1	56.0
Girls, St. Bartholomew's Ward	41.7	44.8	48.1	53.1

An important project of city planning is that of zoning, which "expresses," to quote Herbert S. Swan in the *American Architect*, "the idea of orderliness in community development." The zone plan tends to strengthen and stabilize real estate values, in short

to bring about improvement in real estate conditions and, more important still, encourages efforts to beautify private home sections by street tree planting and the creation of garden streets. Unquestionably, the excellent suggestion contained in a Bulletin of the American Civic Association to the effect that iron fences be substituted for board back fences and board side fences should be adopted. The use of wire and iron for such fencing would not obstruct air-currents as do board fences; and the former "invite flowers and backyard gardens" and "spur competition in cleanliness, neatness and attractiveness." No city should be content without a comprehensive scheme or program for its orderly development to which no single factor would contribute more in the way of beauty and physical benefit than a proper park system including adequate playgrounds.

Trees, as all know, appeal strongly to man's esthetic taste, and this is even more true of an aggregation of trees, shrubbery and flowers, such as may be seen in public squares and city parks. The fact that these vegetable forms exercise certain moral effects, especially a softening and refining influence upon human mind and character, is not open to dispute, but it is scarcely appreciated to the extent that it so richly deserves. City parks adorned with trees, foliage plants and blooming vegetation tend to delight the mind, to divert the attention and relieve ennui. Who has not felt keen pleasure at witnessing the gorgeous beauty of a Rittenhouse Square, or a Campanile in spring-time, or failed to experience the benefit they confer in ministering to his or her esthetic taste and gratifying the senses? Here it should be insisted that there is every reason why we should have displayed in our city parks true art, which should be, however, based on the delicate realities or really beautiful things of nature, with a minimum of human imagination and invention. There is opportunity in this connection for the artist who makes a clear-eyed study of the divinely settled trees, shrubs and flowers which enter into the making of our city squares in their true form.

While parks serve as a place of rest and relaxation, the presence of trees and flowering plants gives a feeling of companionship often tending to brighten and cheer the lonely hours of many who have little opportunity to enjoy life. The writer fully concurs in the view so happily expressed by the London *Medical Record*, namely, that "growing plants and flowers is valuable *delassement* for the weak and weary."

The principal object of this article, however, is to show the value of city parks, open spaces, playgrounds and the like as sources of health and strength, if rightly used. The view is generally held

that a high average physique is the most valuable asset that a municipality, state or nation can boast. Health means freedom from illness, but more than this it means the possession of a reserve force necessary to meet the emergencies of life. The recent war has shown that the American race is distinctly inferior from a physical viewpoint, the percentage of those defective in body among the young men who applied for service being as high as 39 per cent.

Experts who have made an investigation into the causes of physical disabilities of our adult population are in agreement that the principal factors are immigration of inferior races and malnutrition, the result of unsanitary conditions under which they live. Improper and inadequate food plays a leading rôle, but it is no more potent as a disabling agency than lack of pure air and sunshine due to congestion. To overcome in a measure at least the evils of overcrowding which prevails so generally in our large municipalities, a sufficient number of open squares—not less than one eighth of the total surface area, appropriately located, is to be advised and encouraged. A proper park system, such as has been projected in Kansas City, Minneapolis and elsewhere in this country should be looked upon as a conspicuous part of the sanitary arrangements of any municipality. It is obvious that a majority of our cities, especially the older ones, are greatly in need of new open spaces in order that their sanitary requirements shall be met.

There are a number of ways in which these breathing spaces or city parks with their foliage and flowers, in right proportion to the population and properly distributed, increase the healthfulness of the citizenry, apart from their esthetic influence and their happy effect in relieving congestion. In the first place they render hygienic service by producing shade, which has a cooling effect, and, moreover, sets the air in motion, giving rise to gentle currents. But the full sanitary significance of city parks, garden streets and parkways is not appreciable without a consideration of two plant functions; they are, first, transpiration, by which is meant the constant evaporation of watery vapor which takes place from their leaf surfaces, and, secondly, the power possessed by scented foliage, *e. g., pine leaves,* and all flowering vegetation (as shown by the writer's experiments)[1] to convert the oxygen of the air into ozone, the natural purifying agent of the atmosphere through its oxidizing properties. That growing vegetation gives off oxygen to the surrounding air in an amount sufficient to improve the quality of this medium for breathing purposes is a fact of much sanitary significance, and one that rests upon reliable experimental evidence.

[1] "House-Plants as Sanitary Agents; Relation of Growing Vegetation to Health and Disease," pp. 133-136.

On account of their function of transpiration trees and plants generally, more particularly those having soft, thin foliage, tend to increase somewhat, and to maintain, a state of equability in the degree of the atmospheric humidity in their immediate vicinity. It is high time to abandon the view formerly dominant that an antagonism due to certain plant functions exists between the animal and vegetable kingdoms. There is a deeply rooted belief that plant respiration impairs the salubrity of the surrounding atmosphere. The results of the experiments by Pettenkofer, however, indicate conclusively that the amount of oxygen absorbed from the air and the percentage of carbon dioxide exhaled as the result of plant breathing are too small to exert any appreciable effect. It can be shown that plants, even blooming plants in a sleeping room, so far from exerting an unhealthy influence, are all the while making the air in a better condition for human lungs by diffusing moisture and generating ozone, not to speak of the affinity resulting from association with these living objects. Parks serve as a ventilating apparatus for cities, introducing, as they do, a greater abundance of purified air than is otherwise possible. Indeed the effect upon the public health and character of an adequate park system is altogether noteworthy.

Among suggested memorials to the soldier dead, nothing surpasses either in point of fitness or durability a city park or a parkway filled with its trees of remembrance. City parks if rightly kept would be flourishing monuments of living, lasting green for this and coming generations. Says the Rochester *Democrat and Chronicle* in this connection, "Not only would such a memorial be a thing of beauty and a joy for many generations by keeping fresh the memories of heroes of the world's great crisis, but it would be a source of comfort in the heart of summer to countless thousands; perhaps, it would save the lives of many in the course of its existence."

It is to be hoped that the project of planting trees along our streets and public highways generally will be vigorously furthered. To quote from *American Forestry*: "By all means let us have trees of remembrance. Let us have them abundantly and for every possible memorial. They are the true monuments, the living memorials God has provided to hallow the holiest memories of every person and of every race."

Another source of national health, strength and happiness from the standpoint taken by the hygienist as well as the political economist is children's playgrounds. Experts concur in the view that childhood is the time to begin to build up the physical reserve of a nation, which is to play so important a rôle in personal enter-

prise and success later in life as well as in municipal progress. It is during the period of public school life that the body is most in need of the strengthening and invigorating effect of suitable muscular activity. Recent investigations in a large number of schools have shown that twenty-five out of twenty-eight children are physically defective. A definite health program therefore should be made a conspicuous part of every public school curriculum, and the acquisition of health among children demands ample provision for play in the open.

Recreation is of value not only in preserving the health of individuals, but also in the treatment of physical and mental ailments. The effects of the garden city movement in Great Britain, already given in tabular form, will serve to emphasize the value to a race or nation of ample opportunity for our growing girls and boys to play out of doors. Moreover, regular and well-supervised recreation exercises are potent preventives of the great white plague and other chronic diseases. Said the International Congress on Tuberculosis recently, "Playgrounds constitute one of the most effective methods for the prevention of tuberculosis and should be put to the fore in the world-wide propaganda for the diminution of its unnecessary destruction of human life." One of the objects of playgrounds is to make them centers of hygienic instruction and to teach proper habits of living and create a love of wholesome outdoor games and sports, with a view to habitually stimulating the normal physiological processes of the body.

Obviously the largest measure of success in carrying out this health-giving measure is to be attained by a study of the needs of the individual. It is not too much to claim that sufficient play, properly supervised, would successfully overcome a large percentage of the physical defects of childhood. Obviously playgrounds must be supplied with suitable apparatus (which is not always the case), if good results are to be expected.

Here mention should be made of the fact that thoroughfares are being set aside as "play streets" in many of our large municipalities. These are to be advised and encouraged as part of a scheme for the physical development of children, but do not compare with especially built recreation or play centers as means to strengthen the nation's youth. The need of more attractive, supervised play spaces with proper equipment is only emphasized by making the most of inherent existing possibilities, as shown by the utilization of our thoroughfares as "play streets."

There would seem to be immediate urgency in the matter of a careful survey of our leading cities with reference to this question of playgrounds. It is well known that Chicago and Philadelphia

lead with respect to the number of children's playgrounds, but up to now we have not this aid to a full appreciation of the status of the subject in an immense majority of American cities. The playground problem is easily one of the most vital questions of our municipal governments to-day, and while the demand of these sources of strength and national reserve outstrip the financial resources in most cases at least, it is time that our best efforts be directed toward the solution of the problem.

It is a present-day axiom that all must work and play; hence playgrounds should also be provided for those of mature age. Says Dr. Hall aptly, "We do not stop play because we grow old, but we grow old because we stop play." We may not agree with those modern experts who contend that out of every twenty-four hours eight are to be devoted to work, eight to sleep and eight to play, but it is a recognized fact that plenty of daily play or recreation exercise is indispensably necessary to avert staleness, inefficiency and even illness. It is not denied that play can take various forms with good effect, as will be pointed out presently. After play we re-enter the fray serene, clear-eyed and confirmed.

The fundamental principle to be borne in mind in the application of recreation exercise or play in the mature adult is that the needs in this respect differ in different classes of individuals. For example, the mental worker requires diversion for the mind into other than the usual channels, but he requires above all else systematic daily muscular activity while at play. *Per contra,* those engaged in manual, laborious pursuits may get sufficient muscular exercise; they are, however, in need of mental relaxation and recreation.

During the late war Uncle Sam was actively engaged in planning playgrounds for the soldier boys during their hours of relaxation. The armistice came, and these playgrounds were not created. The need of a place and opportunity to play, not only for soldier boys, but for the entire mature population is quite as important during peace times as during war times. There is no reason why adults should not utilize the school recreation centers and children's playgrounds at certain periods of time, but they must not be allowed to crowd out the young. The social and industrial life of an urban community would be vastly improved by the building of an adequate number of playgrounds for the use of parents and of older brothers and sisters of our school children, in short for the whole adult population. While play for children of school and pre-school age is an important factor in the making of future generations of men and women, it would be profitable indeed for the general public to maintain its interest in, and im-

prove every opportunity to dedicate itself seriously to, healthful forms of recreation in the open, such as can be arranged for in appropriate open play spaces.

A campaign for the purpose of arousing public sentiment for the better protection of our national parks would be timely, since these with their natural scenic and historic features should at all hazards be preserved as great and unique public playgrounds Unquestionably, they should be withdrawn from commercial and industrial developments, which have been permitted in recent times. It is to be hoped that the government will formulate a definite policy that would be in conformity with an effective, broad program calculated to gratify every friend of the national park system and thus protect our actual and vital public interests. The country stands in need of the development of more abundant recreation opportunities.

FINNISH POETRY—NATURE'S MIRROR

By Professor EUGENE VAN CLEEF
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OUT of the mêlée of the world's masses of struggling humanity striving during the past eight years to attain "a place in the sun," there has been born a new republic—the Republic of Finland. The birth of this republic was the signal for a glorious Finnish celebration, for it marked the termination of century-old efforts to throw off the yoke of a Russian autocracy. The Finnish declaration of independence attracted the entire world. The great powers affixed their stamp of approval and turned to other world affairs perhaps of greater significance. However, for the Finn the event was notable. He may now and for generations to come, with justifiable pride, tell to his children the story of the "Declaration of Independence" of December 6, 1917, and of the Constitutional law of June 14, 1919, whereby Finland officially declared herself a member of the world family of republics.

The Finns are a unique people. The development of their nationalistic spirit is likewise unique. This spirit was crystallized by the conversion of their folk-song into a national epic—the Kalevala, an epic ranking in quality and originality with the Iliad, the Odyssey and the Niebelunge. The Finns are an imaginative folk, a characteristic they owe to their oriental ancestry. There is little doubt that the first settlers in Finland migrated from central Asia, probably from the region of the Altai mountains. They brought with them a high regard for the controlling influences of the laws of nature and an unequalled devotion to the out-of-doors. They deify the elements of nature, and list among their gods, the God of Waters, God of Forests, God of Fire, God of Breezes and numerous others. Their mythology is essentially a nature worship. In the Kalevala it finds its best expression.

For the composition of the folk-songs into epic form, the Finns are indebted to Elias Lönnrot, first a physician and later a professor of the Finnish language. He appreciated the beauty, the charm and the rare culture expressed by the Finnish folk-songs and resolved that they should be preserved to posterity. These verses, sung through the ages, had never been recorded, so Lönnrot determined to collect them. He traveled to the remotest parts of

Finland where modernisms had not yet penetrated and as he listened hour after hour to the singing of the peasantry, faithfully recorded each canto. Most of the songs were collected in the remote northern portions of the province of East Karelia. Returning home with his note-books bulging with invaluable records, Lönnrot knitted the verses into a homogeneous whole of some 27,000 lines, and in 1835 gave to the world the results of his years of untiring efforts—the Kalevala.

The Kalevala brought home to the Finns the realization of a common language. For the first time did they appreciate the possession of a language meriting the same consideration as Russian, German, Swedish or other recognized national tongues. They further saw the basis for a sympathetic bond among all the Finns and so, almost as soon as Lönnrot's magnificent work made its appearance, it was hailed as the epic of the Finnish people. The Kalevala marked the virtual beginning of an intensive spirit of nationalism throughout Finland.

While all writers do not credit the Kalevala as a true epic, nor wholly discredit it as such, nevertheless they regard the production as extraordinary and certainly approaching closely to an epic. In any event, be it an epic or nearly so, there is agreement as to the uniqueness in its style, in the beauty of its conceptions and in its dramatic presentation of the struggle for existence among a people never known to flinch under the stress of nature's most discouraging environment.

Before detailing the content of the Kalevala, it is of interest to note the peasant's manner of singing the runes. The singers seat themselves upon low benches or stools, and facing each other with outstretched arms, take hold hands; then, as they sway their bodies to and fro in see-saw fashion, first one sings a song and then the other. The singing and see-sawing continue until one or the other runs out of verses. Sometimes others in the party take the places of those who have just finished and either repeat verses or begin a new series constituting a new rune. The meter is unrhymed. It is like that in Longfellow's "Song of Hiawatha." In fact, Longfellow was so impressed with the Kalevala that he admittedly patterned his song after it and it is said even borrowed some of the characters and incidents. The singing is accompanied by the playing of the kantele, an instrument similar to the dulcimer. The music itself is in a minor key and as it is sung resembles more nearly a chant than a melodious air.

The Kalevala, composed as it is of the folk-songs of a people largely if not wholly dependent upon their own ingenuity for the gaining of a livelihood, is really the story of the struggle of the

Finn to overcome the titanic handicaps set against him by nature. His "land of a thousand lakes" is a land of *thousands* of lakes, a land of vast swamps with only here and there a diminutive area suitable for cultivation. The lowland depressions invite premature frosts which often destroy in a night crops representing the hard labor of many months. No surplus of foods to be consumed during periods of scarcity can be accumulated where frost is master. Not only are products of the soil scant, but raw materials for manufactures are limited. The hardy forests for lumber and pulp and the numerous rapids for power send a ray of hope down the Finn's uncertain pathway toward success. Yet in the face of these limitations the Finn has plodded on patiently and uncomplainingly until to-day he has attained a place among the peoples of the earth which many may well envy.

The Finnish farmer is constantly threatened by frost. He knows not when or where it will fall next. A robber-band could hardly worry him more, for there would be some hope of resistance or escape, but the frost is not to be fought nor does it discriminate as to its prey. No wonder, then, that in the national epic Frost is personified and its destructive propensities narrated. In Rune 30 of the Kalevala, Frost interrupts the progress of Lemminkainen, one of the four heroes of the story, who proposes an attack against Pohjola, the North Country. (This region is now represented by Lapland.) Here he had previously gone upon an unsuccessful venture to woo the daughter of Louhi, Mistress of Pohjola. Lemminkainen remonstrated with Frost in no uncertain terms and describes him as follows:

. . . Evil-born and evil-nurtured,
Grew to be an evil genius,
Evil was the mind and spirit,
And the infant still was nameless,
Till the name of Frost was given
To the progeny of evil.

Then the young lad lived in hedges,
Dwelt among the weeds and willows,
Lived in springs in days of summer,
On the borders of the marshes,
Tore the lindens in the winter,
Stormed among the glens and forests,
Raged among the sacred birch-trees,
Rattled in the alder branches,
Froze the trees, the shoots, the grasses,
Evened all the plains and prairies,
Ate the leaves within the woodland,
Made the stalks drop down their blossoms,
Peeled the bark on weeds and willows.

The heavenly bodies as well as the elements of the earth are humanized and deified. They are removed and replaced and caused to perform as circumstances may dictate, with a facility such as characterizes the most magnificent flights of the imagination. Louhi, Mistress of Pohjola, hides the Sun and Moon when the heroes Ilmarinen, Wainamoinen and Lemminkainen organize an expedition against her in order to rob her of the Sampo—"the talisman of success." Her resistance is finally overcome and she is forced to restore the Sun and Moon. The restoration (in Rune 49) is accomplished and Wainamoinen, Son of the Air and of the Virgin of the Atmosphere, a minstrel of magic power, observes the return of these heavenly bodies and recites as follows:

Greetings to thee, Sun of fortune,
Greetings to thee, Moon of good-luck,
Welcome sunshine, welcome moonlight,
Golden is the dawn of morning!
Free art thou, O Sun of silver,
Free again, O Moon beloved,
As the sacred cuckoo's singing,
As the ring-dove's liquid cooings.

Rise, thou silver Sun, each morning,
Source of light and life hereafter,
Bring us, daily, joyful greetings,
Fill our homes with peace and plenty,
That our sowing, fishing, hunting,
May be prospered by thy coming
Travel on thy daily journey,
Let the Moon be ever with thee;
End thy journeyings in slumber;
Rest at evening in the ocean,
Glide along thy way rejoicing,
When thy daily cares have ended,
To the good of all thy people,
To the pleasure of Wainola,
To the joy of Kalevala!

A cheerful aspect of the Finnish environment is presented in the Farewell song (in Rune 24) of the daughter of Pohjola who has become bride of the smith and craftsman Ilmarinen. This song paints a landscape to whose attractiveness those can well attest who have tramped across Finland's fens or through her forests.

Send to all my farewell greetings,
To the fields, and groves, and berries;
Greet the meadows with their daisies,
Greet the borders with their fences,
Greet the lakelets with their islands,
Greet the streams with trout disporting,
Greet the hills with stately pine trees,
And the valleys with their birches.

Fare ye well, ye streams and lakelets,
Fertile fields and shores of ocean,
All ye aspens on the mountains,
All ye lindens of the valleys,
All ye beautiful stone lindens,
All ye shade trees by the cottage,
All ye junipers and willows,
All ye shrubs with berries laden,
Waving grass and fields of barley,
Arms of elms, and oaks and alders,
Fare ye well, dear scenes of childhood,
Happiness of days departed.

Ilmarinen returns (in Rune 25) to Wainola with his Pohjola bride, to receive an heroic welcome at the hands of Lakko, hostess of Wainola. Lakko recounts in great detail the numerous comforts awaiting the bride and concludes with a few effective words descriptive of the village setting. This description characterizes equally well a typical Finnish farm location of the present day.

Thou hast here a lovely village,
Finest spot in all of Northland,
In the lowlands sweet the verdure,
In the uplands, fields of beauty,
With the lake-shore near the hamlet,
Near thy home the running water,
Where the goslings swim and frolic,
Water-birds disport in numbers

The Finn's favorite trees are the gracefully clustered white-trunked birch, the stately symmetrical towering evergreen and the cheerful red-berried mountain ash. The birch is the most economic tree, for in addition to fuel it supplies numerous utensils. Wainamoinen (in Rune 44) wandering across the field and through the forests seeking his lost kantele, comes upon a weeping birch. He inquires into all this sadness and the tree responds as follows:

. . . I, alas! a helpless birch tree,
Dread the changing of the seasons,
I must give my bark to others,
Lose my leaves and silken tassels.
Often come the Suomi children,
Peel my bark and drink my life-blood;
Wicked shepherds in the summer,
Come and steal my belt of silver,
Of my bark make berry baskets,
Dishes make, and cups for drinking.
Oftentimes the Northland maidens
Cut my tender limbs for birch brooms,
Bind my twigs and silver tassels
Into brooms to sweep their cabins;
Often have the Northland heroes

Chopped me into chips for burning;
Three times in the summer season,
In the pleasant days of springtime,
Foresters have ground their axes
On my silver trunk and branches,
Robbed me of my life for ages.

Thus the valued birch acquires personality and through the words of the folk-song permanent expression is given to the Finn's appreciation of its services.

No discussion of Finnish life could possibly be considered complete without reference to the bath. The Finn swears by the bath. It is an institution of no mean value, for it not only helps him preserve his health but, to his mind, serves also as a cure for all ills. The bathhouse is one of the first of the numerous structures to be erected upon a Finnish farm site. It is a small frame shack containing a glacial-boulder fire-place. The fire-place projects well into the room and is without a chimney. A hole in the roof of the building permits the smoke to escape, or sometimes the cracks between the timbers are relied upon as substitutes for the chimney.

In the preparation of the bath, the stones of the fire-place are first heated to a high temperature. Then the fire is put out and cold water is thrown upon the stones. Great clouds of condensed steam fill the room. Around the walls of the room are shelf-like platforms upon which the bathers lie. As the steam stimulates the blood circulation, the bather beats himself with a bundle of birch or aspen twigs. After some ten or twenty minutes immersion in the steam, he enters a small adjoining room and there throws cold water upon himself. The cold "shower" is sometimes applied out-of-doors instead of in a room. He then retires to his house to dress. In winter it is not unknown for a bather to roll in the snow immediately after the bath. The shock of course is great, but with training from childhood the Finn withstands the ordeal and develops tremendous physical endurance.

The Finn's faith in the bath is unbounded and to find it immortalized in his national epic is rightly to be expected. In the "Birth of the Nine Diseases," (Rune 45), there follows an interesting description of the bath and a prayer that its curative qualities may endure:

Wainamoinen heats the bathroom,
Heats the blocks of healing sandstone,
With the magic wood of Northland,
Gathered by the sacred river;
Water brings in covered buckets
From the cataract and whirlpool:
Brooms he brings enwrapped with ermine,
Well the bath the healer cleanses,

Softens well the brooms of birch-wood;
Then a honey-heat he wakens
Fills the room with healing vapors,
From the virtue of the pebbles
Glowing in the heat of magic,
Thus he speaks in supplication.
"Come, O Ukko, to my rescue,
God of Mercy, lend thy presence,
Give these vapor baths new virtues,
Grant to them the powers of healing . ."

Reference has been made to the minor key in which these runes are sung. Finnish music is impressive because so full of character. Its melodies reveal nature's severity, yet they also reflect her forebearance. Life is never so hard but that it has its compensating days. So the minor key reflects at times a somewhat sombre atmosphere and a certain degree of sadness, yet the absence of heavy accents helps to create a feeling of hopefulness and high spirit. One easily recognizes the rushing streams with alternating rapids and reaches, or the clear sparkling glacial waters playing in the brilliant northern sunshine. Nature seems to direct in every song.

The Finn, stolid and phlegmatic at times, but persevering and tenacious, possessed of remarkable physical endurance and a stout heart, has given his brain cells opportunity for growth. His countrymen show the highest percentage of literacy among the nations He loves to read. In his long hours of solitude he digests his readings and allows his imagination full freedom to build upon the ideas absorbed. Thus the Finn has evolved a vivid imagination which has contributed to the development of literature of exceptional merit. His poetry, including both folk-songs and modern works, having been conceived amid the influences of nature, show her unmistakable impress. The reflection of the environment is perfect, and in the Kalevala, especially, the character of Finnish life is accurately and strikingly imaged.

WHAT IS INTELLIGENCE AND WHO HAS IT?

By Professor LIGHTNER WITMER
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INTELLIGENCE is the ability to solve a new problem. An unsurmounted difficulty is a new problem so long as its solution is unknown. It is easy enough to cut the Gordian knot, or to stand an egg on end, after one has learned how these historic intelligence tests were solved. When a problem is difficult enough, or the solution sufficiently novel and important, the intelligence displayed in successful invention will be considered "genius."

Life confronts us with problems, new and old. Just to keep one's self alive is a very old one. "To live by one's wits" is to solve it by an exercise of intelligence. From the cunning of a horse trader to the genius of an Aristotle is a long step up on the scale of intellectual competency, but intelligence may appear at any intellectual level, even a low one, and is divined from what the individual makes of opportunity and resources. We ascertain how much knowledge and skill enter into a performance in order to disregard them, for the intelligence displayed in successful adventure is measured not by the resources employed, but by the risks involved and the difficulties overcome. If, for example, the Russian Soviet is in fact a weak form of government, and the Bolshevists are as entangled in ignorance, insanity and crime as would appear from the reading of our daily newspaper, then it follows that the intelligence of a Lenine or a Trotzky must be given a higher rating than the genius of statesmen who have tried in vain to sink this defective ship of state, despite the fact that they have had at their command the intellectual resources of the most cultured and efficient nations of the world. Intelligence is not to be measured by conventional standards, but by the successful outcome of performance. The discrimination of intelligence from other abilities is concerned only with the criteria that distinguish the variable and novel creations of free initiative from the more constant and familiar effects of established habits. The originality of a performance is proportional to the number of novel elements entering into its composition, and to the amount by which a successful creation of the productive imagination varies from the prevailing mode.

The really serious problems of daily life, the primeval and yet

recurrent problems of mere existence were solved long ago by our pre-human ancestors. As a consequence, we are now able to get up in the morning, cook and eat our breakfast, swallow and digest it, without an exertion of intelligence or intellect, employing for the purpose inherited habits which are physiological mechanisms called "instincts" and "reflexes." Throughout a busy day, full of varied performance, one gets on with the day's work, solving problem after problem, many of them difficult enough, some of them possibly beyond the proficiency of all but the most expert or the best informed; but rarely will a new problem emerge from the comfortable routine of a well-ordered existence.

Education is the device of civilization to keep us from encountering new problems. The method employed is showing the pupil how to solve problems instead of letting him solve them for himself. It thus makes the exercise of his intelligence unnecessary. The school presents the paradigm, and when life confronts the graduate with a new problem, he solves it by virtue of an acquired intellectual habit, and in conformity to the scholastic model.

Endow a child with intellect, let him acquire knowledge and efficiency, teach him to conform his conduct, thought and feeling to the prevailing mode, and you go far to assure him a useful life at a high intellectual level. If he has intelligence, it may facilitate the schoolmaster's task, but pupil and teacher can, and do, get along without it. They must, however, avoid an excess of stupidity. They must not try to solve new problems if every attempt brings failure. They must do what the timid do, who fear failure more than they desire success; they must check initiative, censor the imagination, suppress revolt, curb aspiration and refrain from adventure. At this task the pupil will be aided and abetted by the greater number of schoolmasters who will direct his progress from the first year of the elementary school to the commencement day, which yields the certificate of intellectual proficiency called a "diploma." To discover how much intelligence the graduate of this educational system really has, one would have to surprise him at a moment when he is confronted by some accidental obstacle in an otherwise well-ordered existence—a missing suspender button, for instance, for which he must quickly invent a substitute, or some other difficulty connected with the sempiternal problem of making both ends meet.

Competency is an aggregate of many congenital abilities, some of them specific abilities, like talking and singing; others more general, like intelligence, intellect, discernment, will and motivation. By the time a child is six years old he will ordinarily display

all his congenital competency, from which the discerning observer may estimate how much ability he has and judge if he has enough to be considered normal. Let six-year-old children of normal competency grow up without instruction in school subjects, and therefore below the point of literacy on the intellectual scale, and they will be arrested in development at the level which defines the low grade imbecile. Let them, however, grow in stature, strength and endurance, in social conformity and sexual proficiency, and they could raise and support a family, if it were not for the difficulties provided by what in our pride we call "civilization." During the war, some imbecile children in the city of Philadelphia, arrested under the compulsory education law, were earning more than the truant officer who arrested them. It is not the inherent difficulty of earning a living and raising a family which makes the task impossible for those whose mental age is not more than six years; it is the grocer, the landlord and the employer, competitors whom they must outwit in the struggle for existence, ease and comfort. Civilization implies an average intellectual level. The farther a man's intellectual level falls below the mode, the more intelligence he will need.

No one has ever devised an intelligence test that tests intelligence and nothing else. In consequence, the results of so-called intelligence tests have significance only when analyzed and interpreted in relation to a particular set of antecedent conditions and attending circumstances. The Binet intelligence quotient, for example, is a measure of proficiency, and in those making low scores it may indicate anything in the way of ability or deficiency except intelligence. We do not observe or measure intelligence—we observe performance and measure its effects. A few intelligent performances will cause us to anticipate more of the same sort, and even an intelligent look may lead us to expect intelligent behavior. Intelligence is not a fact, but an explanatory concept derived from the observation of facts. It is a diagnostic category like courage or honesty, the diagnosis being in effect the verbal expression of an expectation.

In order to test the ability to solve a new problem, an intelligence test must provide that many members of a homogeneous group will fail, and that all but a few will make many errors before they achieve success. Those who make many attempts in a given time are more likely to succeed than those who make only a few attempts. Intelligence, therefore, is directly proportional to initiative and inversely proportional to the number of errors made, provided the errors are not too few. To measure a performer's intelligence one must know the time required to achieve success, but one must

not neglect to observe the performer at work and to take into the consideration the number and kind of errors made and how he corrects them. Intelligence is displayed through the operation of trial and error. An intelligence test is adjusted to the intellectual level of a group when those who succeed do not outnumber those who fail.

At the Psychological Clinic, an eleven block formboard is employed as an intelligence test. It may be solved in eleven moves in about eleven seconds, but anyone who solves it thus displays efficiency not intelligence. This formboard is an intelligence test at or about the four year old intellectual level, because not more than 50 per cent. of four year old children are able to solve it, even with a time allowance of one hundred seconds. No two year old child has ever passed the test; about 25 per cent. of three year old children have passed it, and approximately 100 per cent. of six year olds. If I know nothing about a particular child except that he is four years old, the odds are even that he will pass the test. If he is three years old, the odds are three to one that he will fail.

Intelligence is displayed in a performance that succeeds against adverse odds; stupidity is failure despite favoring odds. At any moment a future of some sort confronts us, and often we have nothing better than a gambler's guess for guide. When the odds favor failure, we have only a gambler's chance of winning; if we plunge and win despite the adverse odds, we have had a gambler's luck. The success of an intelligent player who uses all the resources at his command to win a fortune, whether at cards or in business, has a very different diagnostic significance from the "dumb luck" of inheriting money or finding it.

Intelligence, then, is a successful leap into the dark. "A man never rises so high," said Oliver Cromwell, "as when he knows not whither he is going." Converting the words of a madman into a slogan of success, Browning thus portrays the morale of the adventurer at the critical moment when success or failure hangs upon the issue of performance:

> There they stood, ranged along the hillsides, met
> To view the last of me, a living frame
> For one more picture! in a sheet of flame
> I saw them and I knew them all. And yet
> Dauntless the slug-horn to my lips I set
> And blew, "Childe Roland to the Dark Tower came."

The achievement of intelligent initiative may be a successful adventure of pioneer or conqueror, the creation of a work of art, a new idea, an invention—some performance, no matter what, so

long as it be original to the performer, the product of an imagination that outruns knowledge, of an ingenuity that outdoes skill.

If this is a novelty to the beholder, it may inspire admiration, appreciation or wonder. If it is too novel, it will arouse distaste, fear and a destroying hatred. The more shocking a product of the creative imagination, the greater the presumption that genius inspired it, provided the production is something worth while.

The American readers of Walt Whitman's "Leaves of Grass" were too shocked to appreciate the singular novelties of thought and diction concealed beneath the innocent botanical title. When he walked the streets of Philadelphia and Camden, he was ignored by those whom a recent French critic calls his "rustic compatriots." Now that French and English writers have discovered him to be the most original of American poets, his peculiar genius is not without honor even in his own country, save only perhaps in those classic centers of intellectual conservatism—the departments of English literature in our universities.

The Declaration of American Independence started a long war; it eventuated in a form of government as new to the Europe of that day as the Russian Soviet is now; it enthused and emboldened the French Revolutionists; it brought in its train the doctrine of self-determination; it helped to promote the Russian revolution and the success of the Irish Sinn Fein; it was signed by men who felt the hangman's noose about their necks, and only the successful outcome of the adventure kept the noose from being drawn tight.

Whitman says:

> I am the sworn poet of every dauntless rebel the world over
> I do not know what you are for (I do not know what I am for myself, nor what anything is for),
> But I will search carefully for it even in being foil'd,
> In defeat, poverty, misconception, imprisonment—for they, too, are great.
> Revolt! and still revolt!

American patriots, those in particular who would be considered sons or daughters of the Revolution, ought to bear tenaciously in mind that resistance to constituted authority, as well as intelligence and compromise, went into the making of our Constitution.

Intelligence, then, plays a lone hand. It is individualism rampant, and may stake livelihood, happiness, life itself against the opinions and concerted actions of a public horrified by the strangeness of its creations. It is a minor group trying to outplay the majority. It is youth and inexperience trying to outdo old age and wisdom. It is eccentricity successfully opposing the prevailing mode.

The judgments of society, like the verdicts of juries, are not always easy to predict, and are susceptible to strange and rapid

transmutation. Not more than a century ago a Unitarian could be stoned on the streets of Boston. To-day, a Unitarian is Chief Justice, a member of the most conservative branch of one of the most conservative governments in Christendom. John Brown's body hardly lay a-mouldering in the grave before his soul went marching on at the head of forces, military and political, which made possible Lincoln's "Emancipation Proclamation," a document destroying much private property, but, nevertheless, acceptable to what had become, by then, the dominant opinion in American politics. When Socrates was condemned to death, his moral teachings were, by due process of law, adjudged subversive of religion and good government, a source of corruption to youth. "When men revile you and persecute you, rejoice and be exceeding glad, for great is your reward in Heaven, for so persecuted they the prophets which were before you."

The non-conforming genius appears to lose; but once dead and safely buried, he lives in monument and story, the stakes he plays for being held by the unborn, while those who seemingly outplayed him join the unknown multitudes that survive, if at all, only in their progeny.

What, then, is success? It is the approbation of the many, or a few, now or at some future time. In the last analysis, it is what the individual himself deems worth while. Originality, therefore, is appreciated non-conformity. Intelligence is successful eccentricity. It is energy so controlled and directed that a worth while pattern of performance is created. Except for the necessity of conforming to some standard of appreciation, and it may be merely self-appreciation, intelligence is free initiative, unconstrained by definite ends. To exercise a man's intelligence, he must be left free to do what he desires; he must be given every opportunity to make mistakes, in the hope that he will profit by experience. If a child falls down, don't pick him up unless he is in imminent danger—let him learn to pick himself up. If men fall into error, don't correct them by telling them the truth; let them flounder in error until they find out the truth for themselves. This is Nature's way of promoting intelligence.

When our first schoolmaster entered the Garden of Eden in the guise of a serpent, and forced Eve to choose between innocence and knowledge, he made the oldest recorded test of human behavior, and Eve responded to it with intelligence. If this "first disobedience brought death into the world and all our woe," it also brought what we hold dear—civilization (we thought it worth fighting for), the home, the church, the state, our educational system, private property and the inventions of intellect and art. Without fully

realizing what she was doing, Eve rejected a life of ease, comfort and machinelike perfection, choosing the hard and devious path that led from Paradise to the civilized communities which harbor her descendants. Her choice assured them a life of toil, discontent and conflict, all the trouble necessary to exercise their intelligence, train their efficiency and develop their intellect. What more successful outcome would you ask of a simple venture into the unknown, inspired by hardly more than curiosity, motivated by discontent, and determined, it would seem, by the spirit of revolt against authority? Curiosity is the mother urge of science and truth; discontent awakens aspiration, and amongst the traits of character most frequently associated with creative imagination are ambition, audacity, aspiration, the love of adventure, and, most significant of all, a disregard of authority, leading perhaps to the defiance of privilege and public opinion. "He had every quality of a great commander except insubordination," Lord Fisher said of the British admiral who lost, or won, the battle of Jutland.

To teach a student to think for himself is to teach him to disregard authority, including his teacher's. For this reason it is not a common practice of the teaching profession, although it receives much enthusiastic verbal appreciation. Parents, however, are not at all hesitant about expressing their disapproval when a child produces some new idea contradicting well-established convictions. The father of Richard Feveril states a parental ideal in these words: "I require not only that my son should obey. I would have him guiltless of the impulse to gainsay my wishes." He would have added "opinions" could he have conceived it possible for these to be called in question.

Freedom of thought began with the liberty of conscience so outspokenly maintained by the Hebrew prophets, of whom the greatest was also the last, the apostle Paul, who borrowed the characteristic freedom of Hellenic thought to project a new religion. Christianity has fostered freedom of thought and action, though not excessively nor hurriedly. Intellectual, like material, possessions are acquired arduously, and, once acquired, they are held with the same bitter tenacity—the old time religion, the old Constitution, the ancient literature and even that intellectual absurdity—the old science. A mother recently wrote to the dean of a scientific school, asking whether a boy who studied engineering there would be exposed to the theory of evolution, because if this were possible, she proposed to send him to some other school. "Why does a professor have to introduce new and debatable topics for discussion in the classroom?" I have heard the question asked even in academic circles. "Isn't there a large enough body of safe

and sane knowledge to occupy his brief periods of instruction?" No doubt the professor is free enough in some institutions to say what he wishes, but the joker is—the professor does not want to say what will subject him or his institution to hostile criticism. For this reason, university faculties do not make a brilliant display of creative intelligence in the intellectual field. Our educational system, as a whole, is distinguished by the conformity it promotes, the mental discipline it trains.

This, doubtless, is as it should be, for successful living is at least ninety-nine parts in a hundred conformity and constraint; only a very small fraction of one per cent. of a man's life can, at the very best, display freedom of thought and action. In no field, however, is it so important to keep the little freedom we have as in the field of intellectual production. And yet thought is so rigidly conformed in this country to 100 per cent. patterns that American genius is not conspicuous for intellectual originality. Some years ago I heard a professor at the University of Rome express the opinion that the development of big business in the United States was an outburst of creative energy similar to that which distinguished Italy during the Renaissance. Do not go to our universities to observe the best American intelligence in action; go out into the business world where great enterprises are successfully put over. There the atmosphere is one of freedom—even from the constraint of honesty and truth. This year the winner of the Nobel prize in literature is Anatole France, an avowed communist; another winner is Premier Branting, the leader of the dominant socialistic party in Sweden. Representative American contributions to art are movies and jazz bands, skyscrapers and railway stations. When America honors the free expression of new ideas without regard to their normalcy, intellectual originality, as well as mechanical invention, may become a conspicuous trait of American character.

The meeting place of intellect and intelligence is interesting. Imagination belongs to the category of intellect, and also to the category of intelligence. Creative imagination produces order out of chaos. As soon as a little child can use the kindergarten peg board, give him one and ask him to put the pegs into the board. He puts in the first one; where shall he put the second, beside the first or at a distance? This is the critical moment. If he puts it, let us say, beside the first, it must be to the right, to the left, above or below. He is now ready to put the third peg in position. If he does what he did with the second peg, he will make a row. A plan appears, a definite order is displayed. If he works without instruction he is producing an order of his own. He is doing

something that has meaning. He displays creative imagination. He is already beginning to develop an intellect. As the spider spins a web from his own body, so the human being weaves patterns of performance, establishes order, rises superior to chaos and produces standards of behavior based on knowledge. This employment of intelligence in intellectual organization is characteristically and typically human. I have tested chimpanzees and other apes, but have never known an ape to create a new order of his own. I have not seen a chimpanzee peg a straight line of his own accord, but I have observed little children doing it as soon as they could grasp the pegs and put them in place.

A civilization is a social order, the average developmental level of a group, it may be large or small. It is to be measured by the number and diversity of material and intellectual resources, but its chance of survival depends on intelligence, that is to say, on its ability to change. The social order of to-morrow is the invention of the few whose intelligence operates at a high intellectual level.

Change is the predominant characteristic of uterine life; stability, of the adult. At what age does the individual begin to stand pat? When does a man lose the ability to get a new idea, to change convictions or a point of view? At any age. Some, indeed, never get a new idea. They imitate in thought the prevailing modes of the social group to which they happen to belong, or to which they aspire. Fifteen, however, is an age at which a great number, perhaps the majority of those who do at least a little thinking of their own, harden into conventional patterns of thought and behavior. Others keep changing and growing intellectually up to thirty, some even up to forty-five, while just a few display to the very end that intellectual pliability which is intelligence informed by acquired knowledge.

A new individual begins to exist at conception with the union of a spermatozoon and an ovum. He will change more during the nine months of uterine life than in the remaining years of his existence. At birth, it has been estimated, he will possess only two per cent. of the original energy of development. He is like a clock, wound up at conception, which keeps running down until it stops at death. At twenty-one he comes of age, able to inherit the family property but already at six years of age he has entered into his heritage of human competency, and has begun to develop his natural resources of intellect and character, of intelligence and skill.

Age advances on a very uneven front. Long before the first gray hair or the first wrinkle, some congenital abilities have hardened into particular modes of behavior. It is then difficult, if not impossible, to change old habits for new. A child, for example,

having learned one language with ease, inclines to stand pat on his accomplishment. He appears to lose some of his original pliability, offers resistance to the acquisition of another language, develops a sort of organic obstinacy, in other situations called "constitutional conservatism." From infancy on, efficiency is being acquired at the expense of general competency. Problems are solved with increasing accuracy and speed, but the ability to solve new problems is greater at the age of six years than at any later period. Youth combines the plasticity of initiative with the efficiency of acquired skill, and thus produces the successful inventions from which a new order is evolved. Old age brings wisdom, but is handicapped by a deficiency of initiative and dislike of change. The vitality of a civilization is directly proportional to the creative intelligence of its young men and young women.

Observation of the behavior of children and adults leads to the conclusion that education can not make the stupid intelligent. Intelligence is a congenital though not inherited endowment, and the amount of it can not be increased by training. Genius is not a product of breeding; its appearance is in the hands of the gods, a result of the fortuitous combination of qualities possessed by the germ plasms entering into the conception of a new individual. The chief condition which appears to favor superior intelligence is the variety of race and family mixture. The more mongrel a people, the more intelligent; the purer the blood, the more stupid. Intelligence would seem to require an inner conflict of cross purposes and opposing impulses. Neither the Jew, the Anglo-Saxon, the Irish, the French, the Italian nor the American is pure-blooded, in comparison with the Prussian Junker, whose blood is purer and older than the oldest of first families in England or America.

In an essay on "Race and Tradition," written more than twenty years before the great war, Darmesteter, a Frenchman, says of Germany: "The misfortune of Germany—what constitutes her momentary strength and will bring about her lasting weakness in the future—is that the element of race is better preserved there than elsewhere. Hence, narrowness of spirit, lack of proportion in her intelligence, of justice in her heart. She lacked that fruitful struggle of contrary forces that limit their excesses by complementing their energies, and that, in recognizing their mutual rights, enlarge the innate narrowness of man, with the result of producing something that has the extent and variety of Nature herself. Germany has remained, and still remains, a thing strangely powerful and painfully incomplete." [1]

[1] Selected Essays, translated by Helen B. Jastrow.

Two hundred years ago, the author of "Robinson Crusoe" paid his respects to those who tried to mobilize the race prejudice of "true born Englishmen" against the followers of William of Orange, in words that some of our "hundred per cent. Americans" might ponder with profit:

> These are the heroes that despise the Dutch,
> And rail at new-come foreigners so much;
> Forgetting that themselves are all derived
> From the most scoundrel race that ever lived;
> A horried crowd of rambling thieves and drones
> Who ransacked kingdoms and dispeopled towns;
> The Pict, and Painted Briton, treach'rous Scot;
> By hunger, theft, and rapine, hither brought;
> Norwegian pirates, Buccaneering Danes,
> Whose red-haired offspring everywhere remains,
> Who join'd with Norman French, compound the breed,
> From whence your true born Englishmen proceed.

There are those who fear for civilization. Of what are they afraid? Civilization is not necessarily threatened, whether by imperialists or communists; *our* civilization may be—the aggregate of our material and intellectual possessions. Creative intelligence, however, is indifferent to the language which transmits the intellectual fruits of man's genius—whether it be Anglo-Saxon or Prussian, Latin or Slav, indifferent even to the color of the hand that bears aloft the torch of enlightenment and progress, let it be yellow, white or black. So far as intelligence and progress are concerned, the future is a sporting proposition, and the sportsman's attitude is to let the best man win.

The general aim of civilization is dominion over nature—the more efficient control of natural forces. There are doubtless some who still think that man's subjection to nature is a law of God, and that a social order once established must not be changed. Progress, however, is inevitable, though privilege and authority, timidity and prejudice will always oppose the creative advance of intelligence. To defy the spirit of progress in the name of either religion or law is superstition; the true prophet is a poet who sees in creative evolution the display of divine intelligence.

What the world needs to-day is more of the optimism of the progressive and a little less of the pathological fear of the standpatter, more faith in creative evolution, more hope of reaching yet higher levels of achievement and more of that freedom from prejudice called charity, another name for love, the productive passion.

SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE II. WASPS SOLITARY AND SOCIAL

IN the preceding lecture I gave a brief account of the rudimentary social life of certain beetles and called attention to the fact that in all or nearly all of them the male cooperates with the female parent in victualing or protecting the offspring. I endeavored to show that all these societies have their inception or *raison d'être* in the specialized feeding habits of the parents and that in all of them the food is of vegetable origin, abundant but not very nutritious in some of the cases (dung and rotten wood in the Scarabæidæ, Passalidæ and Phrenapates), in others highly nutritious, but obtainable only in small quantities at a time (living plant-tissues and honey-dew in the case of the Tachigalia beetles, ambrosia of the Ipidæ and Platypodidæ). The adequate exploitation of such food-supplies is necessarily time-consuming and has evidently led to a lengthening of the adult lives of the beetles. This in turn has naturally brought about an overlapping of the juvenile by the parent generation, thus enabling the parents to acquire contact and acquaintance with their young and an interest in providing them with the same kind of food as that on which they themselves habitually feed. In the insects which I shall consider in this lecture, we find a series of societies originating in a very different type of feeding and leading to much more complicated and more definitely integrated associations.

Although the wasps have attracted fewer investigators than the ants and bees, they are of even greater interest to the student who is tracing the evolution of specialized instincts and social habits. The wasp group is one of enormous size and is really made up of two great complexes, the Sphecoids and the Vespoids, together comprising more than a dozen families and some 10,000 species. Of these only about 800 are clearly social. We have more or less fragmentary behavioristic studies of scarcely 5 per cent. of all the species. Yet they cover a sufficient number of forms to enable us to establish the following generalizations:

(1). The structure and behavior of the Sphecoids and Vespoids

[1] Lowell Lectures.

show that they must have arisen from what have been called Parasitic Hymenoptera, and the structure of the ants and bees shows that they in turn must have arisen from primitive Sphecoids or Vespoids.

(2). The social wasps comprise several groups which have evolved independently from primitive, solitary Vespoids, but there are also a few Sphecoids that exhibit subsocial propensities.

(3). Both the Sphecoids and the Vespoids are primarily predaceous and feed on freshly captured insects, but the adults are fond of visiting flowers and feeding on nectar. Some social wasps store honey in their nests, but it is probably not an exclusive or essential constituent of the larval food. One small and aberrant group of solitary Vespoids, the Masarinæ, however, provision their cells with a paste of honey and pollen, like the solitary bees. The insect prey on which at least the young of nearly all the wasps subsist, being extremely rich in fats and proteids, is an ideal food, but has to be provided in larger quantity than such concentrated vegetable substances as pollen and nectar. It is also scarcer and more difficult to obtain. Hence the definite tendency in adult wasps towards a honey regimen at least for the purpose of eking out the primitive animal diet.

(4). We are able to observe in the social wasps more clearly than in other social insects the peculiar phenomenon which I have called "trophallaxis," *i. e.*, the mutual exchange of food between adults and their larval young.

(5). The study of the wasps and of their ancestors among the Parasitic Hymenoptera furnishes us with a key to the understanding of parthenogenesis and the peculiar dominance of the female sex (gynarchy) which is retained throughout the whole group of stinging Hymenoptera (wasps, bees and ants).

(6). In the social wasps we witness the first gradual development of a worker caste and also of polygyny and swarming.

(7). We observe in wasps a high degree of modifiability of behavior and an extraordinary development of memory, endowments which have led McDougall to claim for them "a degree of intelligence which (with the doubtful exception of the higher mammals) approaches most nearly to the human," and Bergson to point to their activities as one of the most telling arguments in favor of his intuitional theory of instinct. Although I believe that these and many other authors have been guilty of some exaggeration the wasp's psychic powers compared with those of most other insects or even of many of the lower Vertebrates seem to me, nevertheless, to be sufficiently remarkable.

We shall have to examine each of these generalizations more closely. Some of them may be considered forthwith, others more

advantageously after the description and illustration of a selected series of species.

Recent studies of the parasitic, or as I prefer to call them with O. M. Reuter, the "parasitoid" Hymenoptera, have revealed certain peculiar traits which recur in a modified form in the behavior of their Sphecoid and Vespoid descendants. But what are these parasitoids? You are all familiar with the fact that a large number of insects regularly lay their eggs on or in plants and that the hatching larvæ devour the plant tissues and eventually pupate and emerge as insects which repeat the same cycle of behavior. There is, however, another immense, but less conspicuous, assemblage of insects that lay their eggs on or in the living eggs, larvæ, pupæ and adults of other insects, and the eggs thus deposited develop into larvæ which gradually devour the softer tissues in which they happen to find themselves. Species that behave in this manner are not true parasites, but extremely economical predators, because they eventually kill their victims, but before doing so spare them as much as possible in order that they may continue to feed and grow and thus yield fresh nutriment just as it is needed. For this reason and also because, as a rule, only the larval insect behaves in the manner described, it is best called a "*parasitoid.*" The adult into which it develops is, in fact, a very highly organized, active, free-living creature, totally devoid of any of the stigmata of "degeneration" so common among parasites, and with such exquisitely perfected sensory, nervous and muscular organs that it can detect its prey in the most intricate environment and under the subtlest disguises.

The parasitoids exhibit another peculiarity which was destined to acquire great importance in their descendants, the wasps, bees and ants, namely, parthenogenesis, or the ability of the female to lay unfertilized eggs capable of complete development. As a rule, if not always, these parthenogenetic eggs develop into males, whereas fertilized eggs laid by the same female develop into individuals of her own sex. Thus the female has become to some extent independent of the male in the matter of reproduction. It will be seen that if the parthenogenetic egg were able to develop into a female, as it frequently does in certain insects like the plant-lice, the male might become entirely superfluous. There are a few insects in which this has occurred or in which the male appears only at infrequent intervals in a long series of generations. But matters have not come to such a pass in the parasitoids or in the wasps, bees and ants, though these insects have perfected another method of reducing the male to a mere episode in the life of the female. Individuals of this sex are provided with a small muscular sac, the

spermatheca, which is filled with sperm during the single act of mating, and this sac is provided with glands, the secretion of which may keep the sperm alive for months or even years. According to a generally accepted theory, the female can voluntarily contract the wall of her spermatheca and thus permit sperm to leave it and fertilize the eggs as they are passing its orifice on their way to being laid, or she can keep the orifice closed and thus lay unfertilized eggs. The mother can thus control the sex of her offspring or if she has failed to mate, or has exhausted all the sperm in her spermatheca, may nevertheless be able to lay male-producing eggs. There seems also to be something compensatory, or regulatory, in this ability of the female parasitoid to produce males parthenogenetically, for if she be unable to meet with a male—and this predicament is very apt to arise among such small and widely dispersed animals as insects—she can produce the missing sex and thus increase the chances of mating for the next generation of females.

Certain facts indicate that the sex of the egg may not be determined in the manner here described, but their consideration must be postponed till they can be taken up in connection with the honey-bee. We are justified, notwithstanding, in regarding the female parasitoid, wasp, bee or ant, after she has appropriated and stored in her spermatheca all the essential elements of the male, as a potential hermaphrodite. The body, or soma, of the male, after mating, thus really becomes superfluous and soon perishes. In the solitary wasps the male is a nonentity, although in a few species he may hang around and try to guard the nest. But in the bees, ants and social wasps he has not even the status of a loafing policeman, and all the activities of the community are carried on by the females, and mostly by widows, debutantes and spinsters. The facts certainly compel even those who, like myself, are neither feminists nor vegetarians, to confess that the whole trend of evolution in the most interesting of social insects is towards an ever increasing matriarchy, or gynarchy and vegetarianism.

Now if we carefully observe a parasitoid while she is ovipositing in her prey, we obtain a clue to the meaning of the peculiar behavior of the solitary wasps which has led Fabre to certain erroneous conclusions and philosophers like Bergson to his peculiar interpretation of instinct. The parasitoid is furnished at the posterior end of her body with a well-developed ovipositor, a slender, pointed instrument for piercing the tough integument of her victim. But this instrument also has another function, namely, that of making punctures through which droplets of the victim's blood may exude and be devoured by the parasitoid. She may often be

seen thrusting her ovipositor into her prey without ovipositing and merely for the sake of obtaining food, or she may feed at a puncture she has made while ovipositing. Obviously feeding and oviposition are here congenitally, or hereditarily conditioned reflexes, to use Pawlow's expression. In other words, the internal hunger and reproductive stimuli, or appetites, are so intimately associated with one another that mere contact with the prey releases either the feeding or the ovipositing reactions, or both. And, of course, both of these reactions are purely selfish, the one being concerned with getting food, the other with getting relief from the discomfort of egg-pressure in the ovaries, and both may initiate elaborate trains or patterns of behavior (instincts). This is true not only of the parasitoids but also of insects in general.

Turning now to the solitary wasps we find that, like the parasitoids, they prey on other insects and that each species of wasp usually has a predilection for a particular species (Figs. 18 and 19), genus or family of insects, or even for a particular sex, as in the case of one of our common wasps, *Aphilanthops frigidus,* which preys only on queen ants. The chief difference

FIG. 18
Dolichurus stantoni of the Philippines dragging a young cockroach (*Blatella bisignata*) to her burrow. x 6. (After F. X. Williams).

between the parasitoid and the solitary wasp lies in the fact that the latter lays her egg on or near her victim after stinging it till it is motionless. The sting is merely the ovipositor which is now used only for defence or for reducing the prey to impotence, while the mouth-parts and especially the mandibles are used for obtaining food. Many solitary wasps, after stinging their prey,

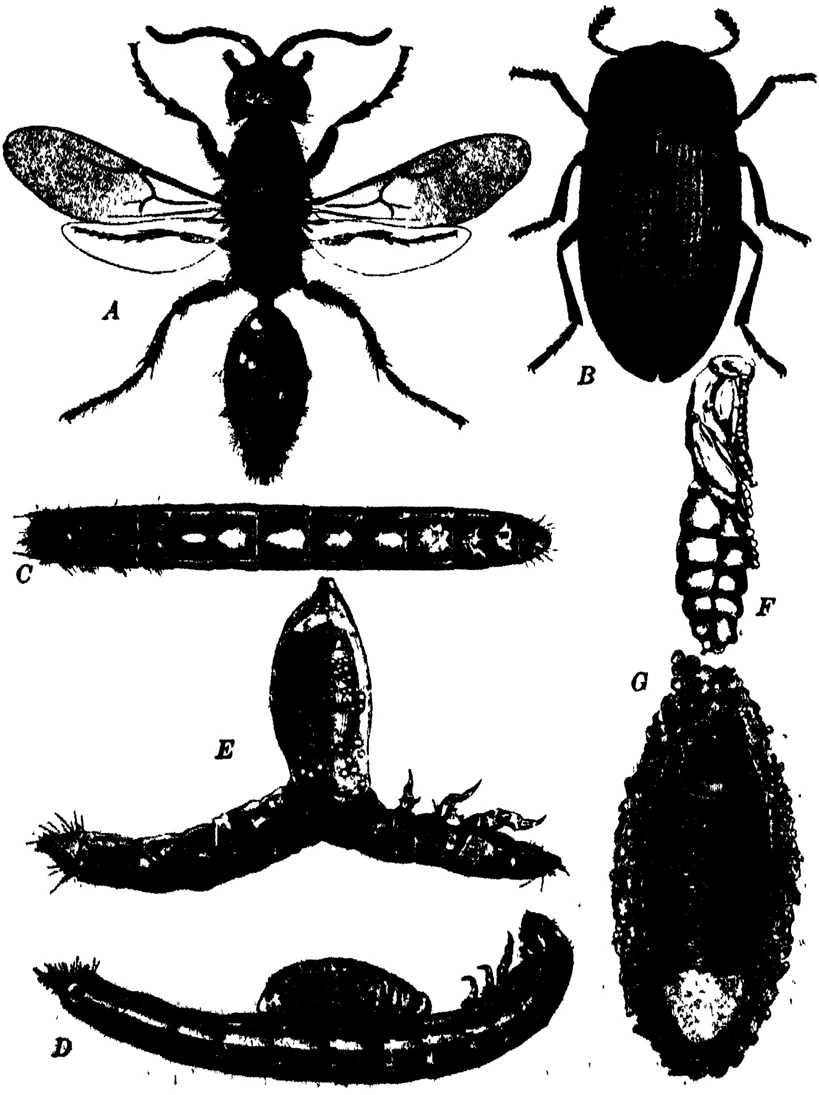


FIG. 19

A. Female of a Bethylid wasp *Epyris extraneus*, of the Philippines; B. Tenebrionid beetle, *Gonocephalum seriatum;* C Larva of the same with egg of *E. extraneus* on middle of ventral surface; D. Young *E. extraneus* larva feeding on the larva of *G. seriatum;* E. Later stage of same; F. Pupa of *E. extraneus;* G. Cocoon of same. (After F. X. Williams).

devour it in part or entirely, or chew, *i. e.*, malaxate, its neck and lap up the exuding juices. This behavior is essentially like that of the parasitoid, and in its more frequent, feebler manifestations may be regarded as a vestigial feeding. The adult wasp is no longer as carnivorous as its ancestors, because she has come to rely to some extent on the energizing nectar of flowers, but this substance contains no proteids and is therefore an improper food for her growing larval young. Roubaud and Rabaud have recently shown that the stinging of the prey follows reflexly as soon as it has been seized and comes in contact with the wasp's sternum, and that the accidental position of the prey when it thus releases the reflex determines the point where it will be stung. Moreover, the stinging is repeated till the victim ceases to struggle and becomes motionless. Hence the stinging does not occur in the schematic manner nor necessarily in the nerve ganglia, as described by Fabre. It has also been shown that the venom introduced into the tissues of the prey by the sting produces paralysis or even death and also acts as an antiseptic in preserving the prey from decomposition for weeks or even months while the larva that hatches from the wasp's egg is feeding on the tissue, but these properties of the venom are accidental and unforeseen. Hence Fabre's and Bergson's contention that the solitary wasp is a clairvoyant surgeon, with an intuitive knowledge of the internal anatomy of the particular insect on which it preys, may be dismissed as a myth.

FIG. 20
Sphex procerus carrying caterpillar of sphinx moth to her burrow. (Photograph by Prof. Carl Hartman).

The explanations here given of the malaxation and stinging of the prey are purely physiological, but it is not at all certain that such explanations are applicable to the entire behavior cycle of the solitary wasp. Before enquiring into this matter, it will be advisable to sketch very briefly the behavior of a typical Sphex as a paradigm of the whole group of Sphecoids and solitary Vespoids. The female Sphex, after mating, digs in sandy soil a slanting or perpendicular tunnel and widens its end to form an elliptical chamber. She may thereupon close the entrance, rise into the air and fly in undulating spirals over the burrow, thus making what is called a "flight of orientation," or "locality study," because it enables her to fix in her sensorium the precise position of the burrow in relation to the surrounding objects, so that she may find the spot again. Then she flies off in search of her prey, which is a particular species of hairless caterpillar (Fig. 20). When it is found, she stings it into insensibility, malaxates its neck, while imbibing the exuding juices, and drags it or flies with it to the entrance of her burrow. Here she drops her victim and, after entering and inspecting the burrow, returns and takes it down into the chamber, glues her egg to its surface and closes the burrow by filling it with sand or detritus collected from the surrounding soil (Figs. 21 and 22). As soon as the next egg matures in her ovaries she proceeds to repeat the same behavior cycle at some other spot. In the meantime the provisioned egg hatches, and the

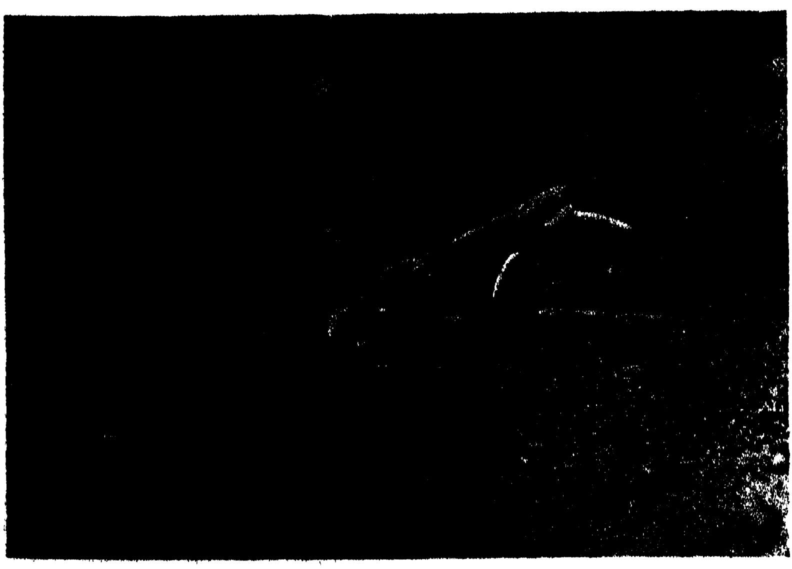


FIG. 21
Sphex procerus carrying chips of wood to throw into the burrow at the left of the figure. (Photograph by Prof. Carl Hartman).

FIG. 22
Burrow of *Sphex procerus* in section, showing filling of débris in the tunnel and the paralyzed sphinx moth caterpillar in the cell, with the egg glued to its side (Photograph by Prof Carl Hartman)

larva, after devouring the helpless caterpillar, spins a cocoon, pupates *in situ* and eventually emerges as a perfect Sphex.

Some of our species of Sphex actually tamp down the filling of their burrows with a small, carefully selected pebble, held in the mandibles and used as a hammer or pestle (Fig. 23). This

FIG. 23
Sphex urnarius using a selected pebble to pound down earth over burrow. (After G. W. and E. G. Peckham).

astonishing behavior, which has been carefully observed by no less than nine investigators (Williston, Pergande, Geo. W. and E. G. Peckham, Hartman, Hungerford and Williams, and Phil. and Nellie Rau) can hardly be reduced to simple physiological reflexes. The same would seem to be true of the orientation flight and return to the burrow and the fact that some species of Sphex provide the egg with a single large caterpillar, others with several small caterpillars, but in all cases with just enough food to enable the larva to grow to the full stature of a normal individual of its species. The question also arises as to the proper interpretation of the peculiar predilection of the wasp for a particular species of prey. This seems to be the more inexplicable, because experiment has shown that the larva can be successfully reared when some very different insect is substituted for the species which it habitually devours. As I am emphasizing the rôle of nutrition in these lectures, I shall digress somewhat on this question of food specialization and in order to bring the matter before you as vividly as possible recast the behavior of Sphex in the form of a tragic drama in three acts, with the following brief synopsis:

Act I. A sandy country with sparse vegetation inhabited by caterpillars and other insects. Time, a hot, sunny day in early August. Scene 1. Miss Sphex arrayed in all the charm of maidenhood being courted by Mr. Sphex. Wedding among the flowers. Scene 2. Mrs. Sphex deserted by her scatter-brained spouse settles down and excavates a kind of cyclone-cellar. She closes its door and leaves the stage.

Act II. Scene 1. Same as in Act I. Mrs. Sphex, hunting in the vegetation, finds a caterpillar, struggles with it, stings it and gnaws its neck till it lies motionless. Scene 2. She drags it into the cellar and placing her offspring on it behind the scenes, returns and at once leaves the stage after locking the door, amid a storm of applause.

Act III. Scene 1. Interior of Mrs. Sphex's cellar. Baby Sphex slowly devouring caterpillar till only its skin remains. Scene 2. Baby Sphex, now a large, buxom lass, weaves an elaborate nightgown for herself and goes to bed as the curtain falls.

As a work of art this drama is defective, because the climax, the stinging of the caterpillar, falls in the early part of the second act, and because the heroine leaves the stage soon afterwards for good, as if she had been suddenly taken ill and had to substitute her drowsy offspring to perform the whole third act. Still this is the sequence in which the drama is related by all the observers, and I have presented my account in the same manner, because it has undeniable advantages. But see what happens when we rearrange

the drama by making the third or last act the first, and the first and second the second and third, respectively. There is then only one heroine who holds the center of the stage throughout the performance. We witness her gradual growth and development from infancy during the first act, her wedding, desertion and cellar-excavating exploits during the second, and the thrilling chase, stinging and entombment of the hereditary victim in the third act.

I have just committed the unpardonable sin of humanizing the wasp, but being desirous of making my point perfectly clear, I am going to do something still more scandalous and ask you for a moment to vespize the human being. Suppose that the human mother were in the habit of carefully tying her new-born baby to the arm-pit of a paralyzed elephant which she had locked in a huge cellar. The baby—we must, of course, suppose that it is a girl baby—is armless, legless and blind, but has been born with powerful jaws and teeth and an insatiable appetite. Under the circumstances she would have to eat the elephant or die. Supposing now that she fed on the elephant day after day between naps till only its tough hide and hard skeleton were left, and that she then took an unusually long nap and awoke as a magnificent, winged, strong-limbed amazon, with a marvellously keen sense of smell and superb eyes, clad in burnished armor and with a poisoned lance in her hand. With such attractions and equipment we could hardly expect her to stay long in a cellar. She would at once break through the soil into the daylight. Now suppose she happened to emerge, with a great and natural appetite, in a zoological garden, should we be astonished to see her make straight for the elephant house? Why, she would recognize the faintest odor of elephant borne to her on the breeze. She would herself be, in a sense, merely a metabolized elephant. Of course, we should be startled to see her leap on the elephant's back, plunge her lance into its arm-pit, drag it several miles over the ground, hide it in a cellar and tie her offspring to its hide.

The point I wish to make is this: We have all along in our accounts treated the life-history of the insect as that of two individuals in such a manner as to obscure or obliterate the experience of the individual. We begin with the full-fledged insect descending from the blue, and then describe her behavior as if it were a pure inheritance or improvisation. But when we describe her activities as those of a single individual from the beginning of her development to death, we find that the adult female, before she begins to make and provision her nest, has probably learned something from her long and intimate larval contact with the environment. For months she has inhabited a chamber like the one she

will excavate or build for her own progeny, for days she has been devouring a particular species of caterpillar and she has even dug a sufficient distance through the soil to be familiar with its properties. She possesses, therefore, a certain amount of acquaintance with soil and with caterpillars. That this should persist as memory is not only possible but extremely probable when we consider that the central nervous system of the larva passes without profound change into that of the adult wasp and that the latter shows unmistakable evidence of possessing a remarkable memory when she makes such locality studies as have been described and returns to her nest or prey after an absence of several hours or even days. We are also enabled to understand why the wasp confines her attention to a particular species or even to one sex of a species while searching for her prey, and why the malaxation or mutilation of the prey may be regarded as a reminiscent act of feeding. In brief, all those activities of the adult wasp which are partly or wholly interpretable as a repetition of larval behavior, may be attributed to memory—not in the sense of recollection, with its feeling of "pastness," but of mere sensory and motor memory, the *memoria sensitiva* of scholastic writers, or the "associative memory" of comparative psychologists.

But there still remain unexplained the more striking activities, those performed for the first time in the wasp's life-history, namely the cocoon-spinning of the larva, the making, closing and opening of the nest, oviposition, etc. No doubt these acts are all initiated by stimuli, partly internal and partly external, such as hunger, the tension of accumulated silk in the spinning glands, of eggs in the ovaries, hormones in the blood, and olfactory and tactile impressions from contact with the caterpillar and the soil, but the reeling off of the train of these purposive responses must depend on inherited dispositions in some way correlated with the structure of the nervous and muscular apparatus. And we must suppose that these dispositions somehow represent the experience of untold former generations of wasps. We are, however, unable to form any adequate conception of the extent of the racial experience of the solitary wasps as a group and therefore of the amount of condensation or syncopation with which it is epitomized in the behavior of the individual wasp, and this disability on our part is largely responsible not only for the old supernatural conceptions of instinct but also for theories like those of Bergson, the Neodarwinians and the mutationists.

We may now turn to the evolution of social behavior, which, in diverging lines of descent, has been gradually evolved and perfected from such a method as that employed by most of the

Sphecoids and non-social Vespoids. This method, which consists in rapidly accumulating an amount of prey sufficient to enable the young to develop to maturity and of then closing the cell before the egg has hatched, we may designate, with Roubaud, as "mass provisioning." We have seen that in some cases the mother wasp stores a single large insect, in others a number of smaller ones, before closing the cell. If in the latter case the accumulation of the prey is delayed on account of scarcity or inclement weather, the egg, which has been glued to the first small insect captured, hatches before the mother wasp has succeeded in collecting a sufficient supply for the growth of the larva. She is therefore reduced to feeding her offspring from day to day, *i. e.*, to what Roubaud calls "progressive provisioning," a method which is seen in certain species of Sphex and Lyroda (*S. politus* and *L. subita*, according to Adlerz) and probably also in *Aphilanthops frigidus*, according to my observations. But the best examples may be observed among the digger-wasps of the family Bembicidæ, on which we possess a number of valuable studies by Wesenberg-Lund, Bouvier, Marchal, the Peckhams, Hartman, Riley, Melander, Ferton, Parker, Adlerz, the Raus, etc. While our large cicada-killer (*Sphecius speciosus*) provisions its burrows with a single cicada, lays an egg on it and closes the cell, thus practicing typical mass provisioning, some other Stizinæ and many species of Bembix and allied genera proceed in a different manner. These insects live in open, sandy places, often in rather populous and compact congregations, though each female makes and provisions her own burrow. The prey of each species of Bembix consists of the common two-winged flies of her environment, without regard to the species. They are stung to death but not mutilated. After the burrow is excavated the wasp kills a small fly and after dislocating one of its wings, places it on its back on the floor of her cell and attaches her egg to its sternum. The dislocation of the wing is supposed by Ferton to be a device for preventing the fly from being turned over by the very delicate young larva and thus insuring it against injurious contact with the rough, sandy floor of the cell. The mother collects flies and brings them into the burrow from day to day, actually increasing the size or number of the victims as they are needed by the growing and increasingly voracious larva. At least one European species of Bembix (*B. mediterraneus*), according to Ferton, lays her eggs on the floor of the cell before bringing in any flies. Instead of flies, the species of Bicyrtes and Stizus provision their young progressively with bugs or leaf-hoppers, and one of our species (*Microbembex monodonta*), according to Hartman, Parker and the Raus, feeds its young on all sorts of small, dead

and dried insects (grasshoppers, beetles, flies, mayflies, ants, etc.) picked up from the soil.

Among several of the solitary Vespoids we find very similar conditions and these are of more immediate interest to us because this group of insects has evidently given rise to the true social wasps. The numerous species of Eumenes and Odynerus (Fig. 24), as well as the allied genera, either excavate their burrows in the ground, or take possession of the tubular cavities of twigs or the interstices of walls, or construct exquisite mud cells above ground on the surfaces of rocks, trees or walls. After the cell is completed the egg is hung by a filament from its ceiling. Numerous small, smooth, paralyzed caterpillars are then brought in and the cell is closed. This is, of course, typical mass provisioning. But Roubaud has observed some very significant modifications of the process in certain Congolese species. Of one Odynerus (*O. tropicalis*) he gives the following account: "This little Odynerus does not

FIG 24
Four stages in the mud nest of *Odynerus dorsalis*. *A*. Showing one cell open and being stored with small caterpillars; *B*. Nest on the following day, showing wasp resting in a new cell made on the previous afternoon. *C*. Nest with one cell opened to show the wasp larva feeding on caterpillars; *D*. Same nest, showing holes made by the escaping wasps. (After Carl Hartman).

provision its cells with prey amassed in advance, but nourishes its larvæ from day to day, with small, entire, paralyzed caterpillars, which are always given to the larva in very small numbers, till its growth is completed. The egg is never walled up in the cell with provisions hastily amassed. The wasp, to judge from what I have been able to observe of its educative procedure, after having laid her egg, watches it within the cell after the manner of the higher species of Synagris till it hatches. As a rule, prey is brought to the egg only at the moment of hatching or a little before, and usually a single small caterpillar, rarely two and never three, is found placed at the disposal of the just-hatched larva. *Pari passu* with the growth of the latter the prey is renewed, but always in small numbers. Sometimes the larva may be seen fasting in the cell while the mother wasp is away in search of prey. Finally, it is only after its feeding has been completed that the larva is immured in the cell. In no case did I observe in closed cells containing larvæ the slightest trace of provisions.'' Even more interesting are the species of Synagris referred to in this quotation. In several of them Roubaud found the following conditions, representing transitions from mass to progressive provisioning:

The female of *Synagris spiniventris* (cited as *callida* by Roubaud) and *callida* (cited as *sicheliana*) under normal conditions, *i. e.*, when food is abundant, lays an egg in her mud cell, fills it in the course of a few days with small paralyzed caterpillars, sometimes to the number of 60 (!) and then closes it, thus adopting the usual or ''banal'' method of mass provisioning. When, however, owing to seasonal or climatic conditions, caterpillars are scarce, the female, after ovipositing and guarding the egg for some time, collects a meager provision of small caterpillars for the hatching larva and while it is growing, continues to feed it in the same manner. After the larva has attained three fourths of its adult size, the wasp immures it in its cell with the last supply of provisions. As Bequaert remarks, ''in *S. spiniventris*, progressive provisioning is still optional, and one observes all the transitional stages between this behavior and the normal provisioning in mass. The mother wasp shows great skill in adapting her habits to the external conditions.'' According to Roubaud another species of Synagris (*S. cornuta*), proceeds a step further (Figs. 25 and 26). The female, after completing her earthen cell, lays an egg on its floor and when the larva hatches feeds it from day to day with pellets made of a paste of ground up caterpillars. This is precisely the method employed by the social wasps in feeding their larvæ!

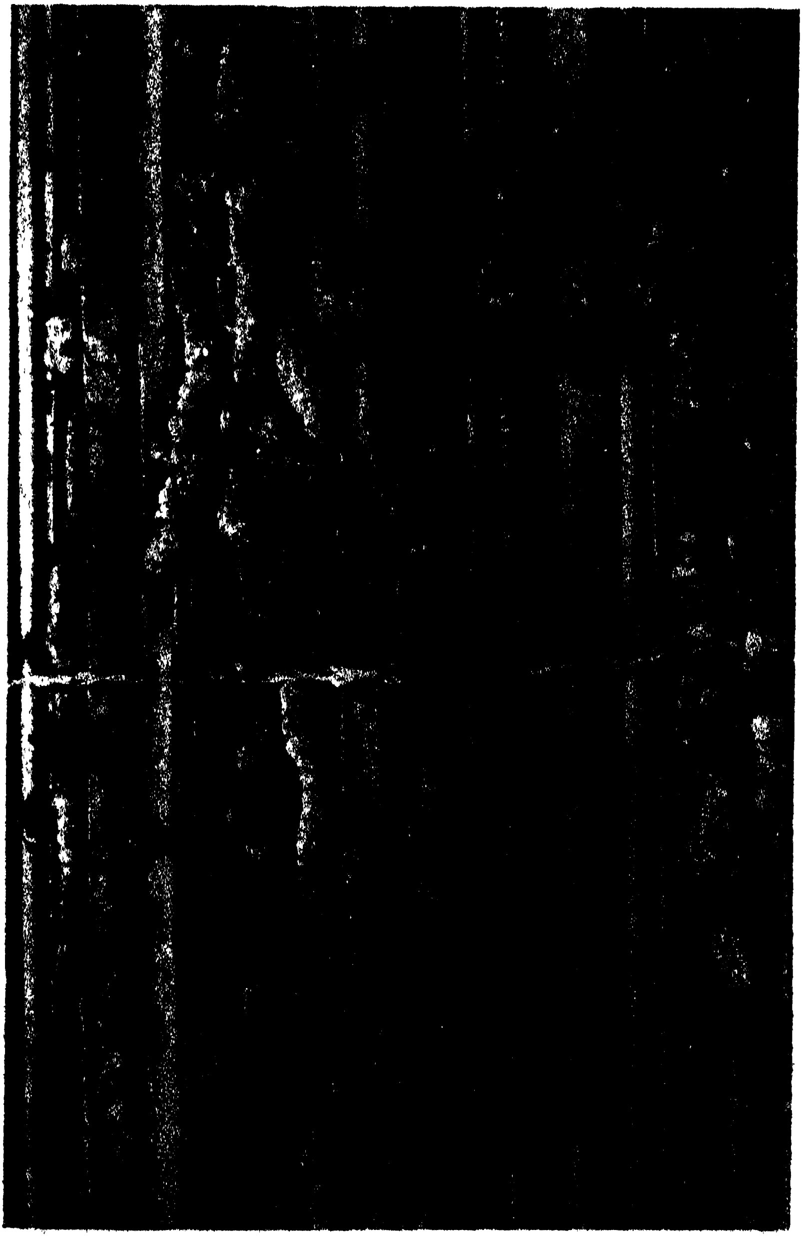


FIG. 25

Mud nests of *Synagris cornuta* on the thatching of a native hut in the Congo. "Some of these nests show very distinctly the short neck with its slightly widened opening curved to the side and downwards. Such a chimney is built at the entrance of the cells containing eggs or larvæ still nursed by a female." (After J. Bequaert from a photograph by H. O. Lang).

A step in the direction of the social wasps seems also to have been taken by a small group of solitary Vespoids, allied to the Eumeninæ, namely the Zethinæ. These insects, which have been studied recently in Brazil by Ducke, in British Guiana by Howes and in the Philippines by F. X. Williams, have abandoned the use of earth as nest material and employ instead small bits of leaves or moss (Fig. 27). With such vegetable material *Zethus* constructs a beautiful nest with one or several tubular cells, and therefore approaches the social wasps which make their nests of paper, a substance consisting of fine particles of wood agglutinated with an oral secretion. The egg is laid loosely in the bottom of the cell and, according to Williams' account of the Philippine *Zethus cyanopterus*, the larva is fed from day to day on small caterpillars, which have been in part eaten by the mother. She faithfully guards the larva and, while it is small and there is still ample room, sleeps in the cell. She closes the latter as soon as the larva is full grown and proceeds to build another.

Each of these cases of progressive provisioning may be regarded as a very primitive family, or society, reduced to its simplest terms, *i. e.*, to a mother and her single offspring. The seasonal or local conditions of the environment, in so far as they affect the abundance or scarcity of prey, have led on the one hand to mass provisioning and therefore to an exclusion of the mother from contact with her growing offspring, and on the other to an establishment

FIG. 26
Mud nest of *Synagris cornuta* var. *flavofasciata* with mother wasp. (After J. Bequaert from a photograph by H. O. Lang).

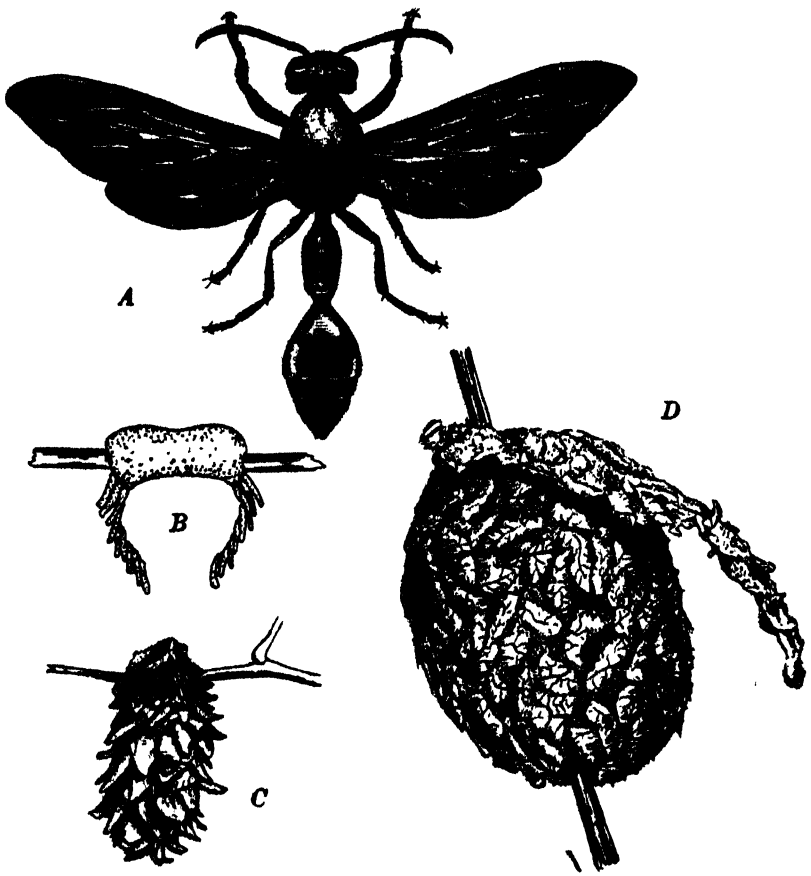


FIG. 27
Zethus cyanopterus of the Philippines and its nest. *A*, Adult wasp x 2, *B*, the beginning of a cell. It is attached to a twig by a mass of well-masticated leaf-bits and the wall of the cell is made of shingled leaf bits (Somewhat enlarged); *C*, the first cell of the nest completed x ¾; *D*, a four-cell nest showing roof-like structure and one emergence hole x ¾. (After F. X. Williams).

of that very contact. This, again, has developed an immediate interest of the mother in her young comparable with what we observe in many birds. Probably this interest is aroused and sustained in the mother wasp by simple, pleasurable, chemical (odor) or tactile stimuli emanating from the egg and larva, but whatever be the nature of the stimuli involved, I believe that we shall have to admit that the egg and the larva have acquired a "meaning" for the mother wasp, and so far as the egg is concerned, this seems to be true even in the species that practice mass provisioning. We noticed that many solitary Vespoids (Eumenes, Odynerus), before they bring in their prey, carefully attach the egg by a string

to the ceiling of the cell. This singular performance has been variously interpreted. Fabre and others regard it as a device for preventing the delicate egg from being crushed by the closely packed and sometimes reviving prey, on the same principle that in a crowded room an electric light bulb attached by a cord to the ceiling would be less easily crushed than one rigidly fixed to the walls or the floor. Others regard the filament as a device for keeping the egg free from the occasionally very damp walls of the cell. Ferton has recently shown that *Bembix mediterraneus* glues its slender egg to the floor of the cell in an erect position and with the base carefully supported by a cluster of large sand-grains (Fig. 28 A), and that *Stizus errans* glues its egg in a similar position

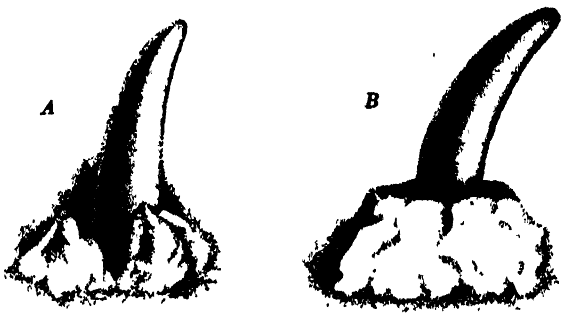


FIG. 28

A Egg of *Bembix mediterraneus* with its base supported by a cluster of large sand-grains *B*. Egg of *Stizus errans* glued to the upper surface of a carefully selected pebble (After C. Ferton).

to the top of a small, carefully selected pebble placed on the floor of the cell (Fig. 28 B). Parker's description of the egg of our *Microbembex monodonta* seems to indicate a condition similar to that of *B. mediterraneus*. In all these cases we seem to have an arrangement for keeping the very easily-injured egg as free as possible from contact with the rough, sandy walls of the burrow. But even the Sphecoids and Psammocharids, which practice mass provisioning, attach the egg to a particular part of the victim and in such a position that the hatching larva can attack it at its most vulnerable point. Ferton, especially, has made a very interesting study of this type of behavior.

The following facts also indicate very clearly that the mother wasp may be aware, not only of sexual differences among her own eggs but also of the differences in the amount of food required by the resulting larvæ. Bordage, while investigating the Sphecoids of the Island of Réunion, found that three of the species, *Pison argentatum*, *Trypoxylon scutifrons* and *T. errans*, could be readily induced to make their cells in glass tubes placed between the

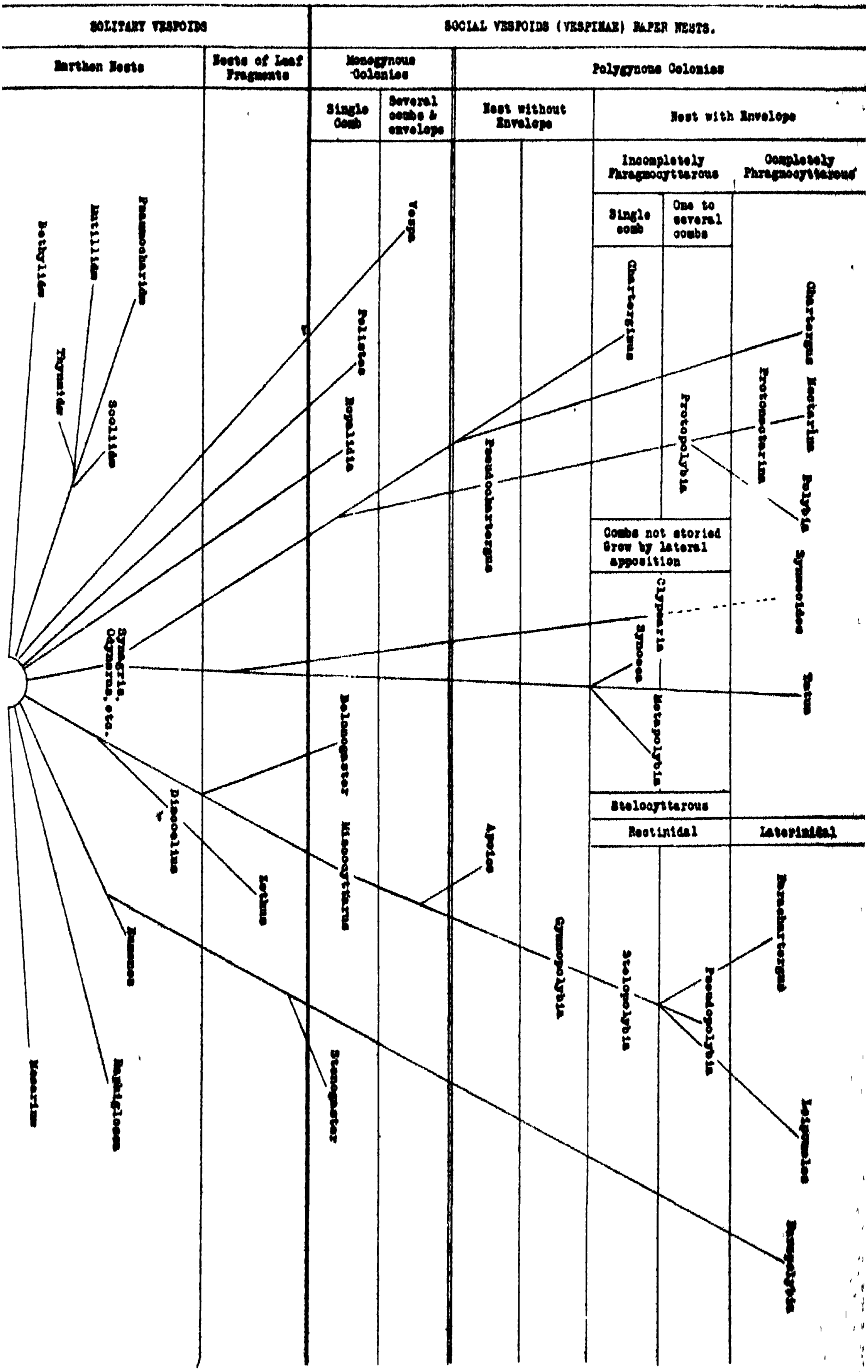


FIG. 29
Phylogenetic tree of the various genera and families of Vespoids. (After Ducke, with modifications).

pamphlets of his library. The Pison, under natural conditions, builds elliptical clay cells and provisions them with spiders, whereas the species of Trypoxylon nest in hollow twigs and the interstices of wall but use the same kind of prey. All these species adapted themselves to the glass tubes in the same manner. Each of them plugged the end of the tube with clay and divided the lumen into successive cells by building simple clay partitions across it. After the cells had been provisioned, Bordage observed that the first of them were longer by half a centimeter and contained more prey than those provisioned later, and he was able to show that the larvæ in the larger, more abundantly provisioned cells produced female, the others male wasps. Similar observations have also been published by Roubaud on the Congolese *Odynerus* (*Rhynchium*) *anceps*, which makes clusters of straight, tubular galleries in clay walls and divides each gallery into several cells by means of clay partitions. In this case also the first cells are much longer than the later, though there is no difference in the quantity of small caterpillars allotted to the different eggs. But Roubaud was able to prove experimentally that even when the amount of food is so greatly decreased that the larvæ produce adult wasps of only half the normal size, their sex is nevertheless in no wise affected. It would seem therefore that the mother wasp must discriminate between the deposition of a fertilized, female-producing and that of an unfertilized, male-producing egg, and regulate the size of the cell and in some instances also the amount of provisions accordingly.

In the accompanying diagram (Fig. 29), taken from Ducke but somewhat modified, I have indicated the hypothetical family tree of the solitary and social Vespoids. The genera below the heavy horizontal line are solitary, and among them Eumenes and Odynerus seem to be nearest to the original ancestors, because they are very similar to the social forms in having longitudinally folded wings and in other morphological characters. It will be seen that there are six independent lines of descent to the social forms above the heavy line and that the genera plotted at different levels represent various stages of specialization as indicated by the nature of the materials and types of structure of the nests. With the doubtful exception of a few Stenogastrinæ, all the social wasps make paper nests consisting wholly or in part of one or more combs of regular hexagonal cells, in which a number of young are reared simultaneously.

(*To be continued*)

THE PROGRESS OF SCIENCE[1]

INTERNATIONAL COOPERATION IN INTELLECTUAL WORK

Steps have been taken toward the formation of a committee of the League of Nations on international cooperation in intellectual work. Eleven of the twelve members have been appointed and as none of them is an American, it is expected that the vacancy will be offered to an American scholar.

The committee so far chosen consists of Henri Bergson, the French philosopher and author of "Creative Evolution"; Madame Curie, the Polish discoverer of radium; Albert Einstein, the German mathematician who propounded the theory of relativity; Gilbert Murray, professor of Greek at Oxford; Miss Bonnevie, professor of zoology at Christiania; D. B. Bannerjee, professor of political economy at Calcutta; A. De Castro, of the medical faculty of the University of Rio de Janeiro; J. Destree, former minister of science and art in the Belgian cabinet; G. De Reynold, professor of French literature at Berne; F. Ruffini, professor of ecclesiastical law at Turin, and L. De Torres Quevedo, director of the electro-medical laboratory of Madrid.

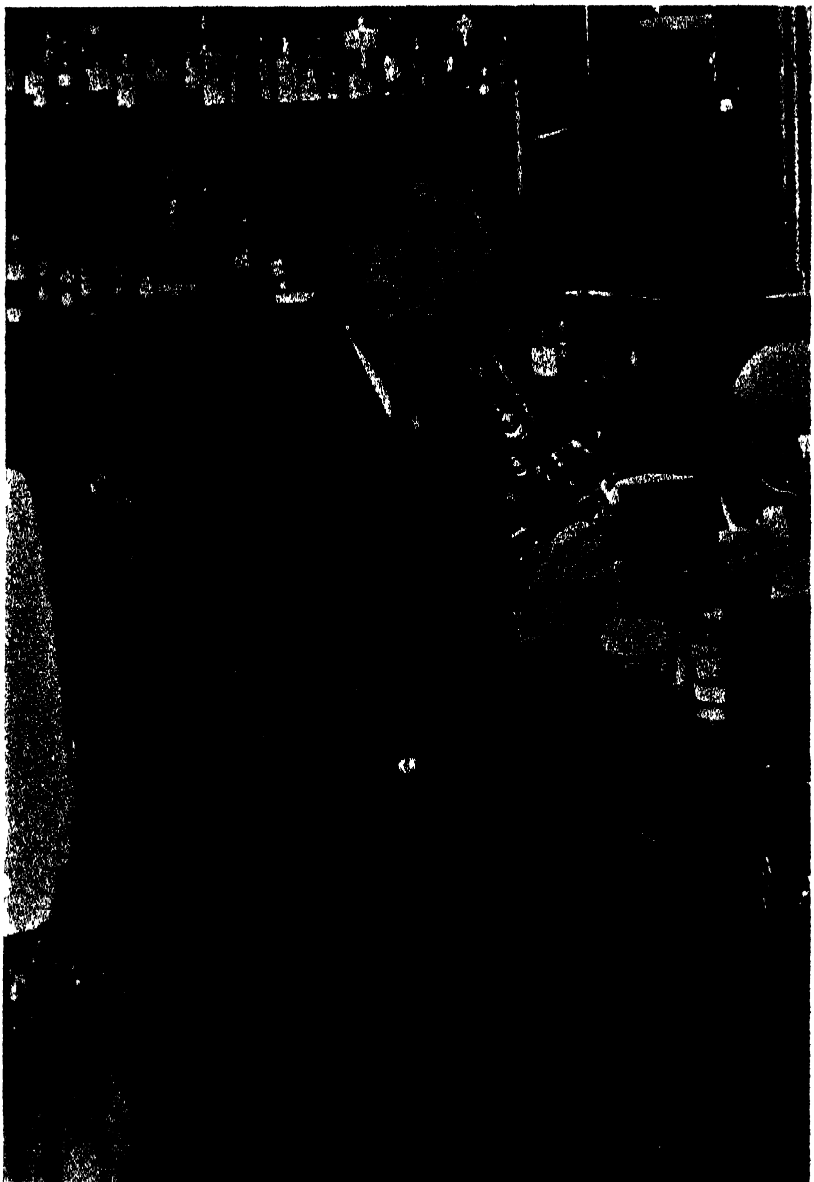
The first meeting of this committee is set for August 1, and a prominent position on the program of work outlined is given to measures that will facilitate the interchange of scientific information and the development of higher education in the countries participating.

With regard to the organization of intellectual work from an international standpoint the report adopted by the council of the League of Nations when the committee on international cooperation in intellectual work was organized says:

> We are all agreed that the League of Nations has no task more urgent than that of examining these great factors of international opinion—the systems and methods of education and scientific and philosophical research. It would be unthinkable that the league should endeavor to improve the means of exchange of material products without also endeavoring to facilitate the international exchange of ideas. No association of nations can hope to exist without the spirit of reciprocal intellectual activity between its members.
>
> For example, it is clear to all how much the league would benefit by any new measures which by establishing a more definite parallelism between the diplomas of the various countries and a more frequent exchange of chairs between professors of various nationalities would lead to a more active interchange of teachers and students between nations. A still greater benefit would result from measures which permitted a more rapid and more accurate communication of all work undertaken simultaneously in the field of scientific research in various parts of the world.
>
> There is no question of detracting from the originality of national workers whose very diversity is essential for the general progress of ideas. On the contrary, the object is to enable each of these national thinkers to develop his ideas with greater force and vitality, by making it possible for him to draw more fully upon the common treasure of knowledge, methods and discoveries.

As a part of the work of the League of Nations, a "Handbook of International Organizations" has recently been issued, which lists 315 societies, associations, bureaus, committees and unions, all of them international in some aspect. It is an interesting collection of religious, scientific and other sorts of organizations, the international association interested in lawn tennis being listed with the entomological, meteorological

[1] Edited by Watson Davis, Science Service.



PROFESSOR SANTIAGO RAMON Y CAJAL

The distinguished Spanish histologist who retires from the chair of histology and pathological anatomy at the University of Madrid on reaching his seventieth year.

and other scientific societies. Such a directory is a necessary preliminary of the activities of the committee on international cooperation in intellectual work.

CALENDAR REFORM

Reform of the calendar has been much discussed during the past decade or more, for the inconveniences and inconsistencies of the present calendar are obvious.

The two schemes which are receiving the largest amount of attention are the international fixed calendar plan and the Swiss plan.

The former, first publicly proposed by Moses B. Cotsworth of Vancouver in 1894, provides for thirteen months in the year, with twenty-eight days to the month, every date being attached to the same day of the week in every month. New Year's Day is a zero day called January 0, and is a full holiday. The extra day in leap year is a similar holiday inserted as July 0. The extra month, which, of course, does not add to the actual length of the year, is introduced between June and July, and is called "Sol." Easter is to be fixed by the Christian churches on some date between March 21 and April 26, this stabilizing an event whose drifting causes inconveniences and losses in business and social life.

The Swiss plan has been advocated largely by astronomers. It also sets aside each New Year's Day and each leap-year day as independent legal holidays. The other 364 days are divided into four quarters of 91 days each, each quarter containing one month of 31 days and two months of 30 days, thus keeping twelve months as at present.

The international fixed calendar plan recently received the unanimous approval of a convention held in Washington by those interested in calendar reform. The American section of the International Astronomical Union, after considering both the Swiss plan advocated by its committee on calendar reform and the fixed calendar plan, recently refused to take action on the matter.

The question of calendar reform was taken up at a meeting of the International Association of Academies held in St. Petersburg in 1913, and a committee was appointed on that occasion "to study questions relative to the unification and simplification of the calendars and the fixing of the date of Easter." This committee would have made a report in 1916, but for the war. Another discussion of this subject took place at the International Geographical Congress held in Rome in 1913. In June of the same year the World Congress on International Associations, which met at Brussels, passed a resolution urging the governments of the world to adopt a universal calendar. Three of the International Congresses of Chambers of Commerce have given expression to the same desire. Finally, just before the outbreak of the world war, the International Congress on the Reform of the Calendar held its sessions at Liège, and not only agreed to urge the adoption of a universal and improved calendar but also made plans for a formal conference, which was to have been convoked in Switzerland at the invitation of the Swiss government. but was never held.

In the future there may come a conference of nations that will adopt a new and more logical calendar as easily as standard time was established by an international conference at Washington about forty years ago.

INVISIBLE SUN-SPOTS

Dr. George Ellery Hale, director of the Mount Wilson Observatory, has announced the discovery of invisible sun-spots. In 1908 Dr. Hale found that a sun-spot is a great whirling storm, similar to a terrestrial tornado, but on a gigantic scale, often vastly larger than the earth. The ex-

Wide World

TWINS ATTENDING A LOS ANG S PUBLIC SCHOOL

pansion of the hot solar gases, caused by the centrifugal action of the whirl, cools them sufficiently to produce the appearance of a dark cloud, which we call a sun-spot. If this cooling is not great enough to produce a visible darkening of the surface, the whirling storm may still be present, though invisible to the eye. Such invisible whirls have now been detected by their magnetic effect on the light emitted by the luminous vapors within them.

Magnetic fields in visible sun-spots were first found by Dr. Hale in 1908. They are due to the whirl of electrified particles in the spot vortex, just as the magnetic field of an electromagnet is produced by the whirl of electrons through its wire coils. The magnetic field in a sun-spot is recognized by the effect it produces on the lines in the spectrum. A line due to iron vapor, for example, is split into three parts by the powerful magnetic field in a large spot. In a very small spot, where the magnetic field is much weaker, the line is not split up but is merely widened.

Invisible spots were discovered by exploring promising regions of the sun where signs of disturbance, such as faculæ or clouds of calcium vapor, are present. A special polarizing apparatus moves back and forth across the slit, while the iron line is watched through a very powerful spectroscope. The presence of a weak magnetic field, showing the existence of an invisible spot, is betrayed by a slight oscillation of the corresponding part of the line, caused by its widening successively to right and left as the polarizing apparatus oscillates over the slit.

Ten invisible spots have been found since November by this method by Messrs. Hale, Ellerman and Nicholson with the 150-foot tower telescope and 75-foot spectroscope on Mount Wilson. Some of them foreshadow the birth of a visible spot, which finally appears to the eye several days after the first indications of the whirl have been found. Others correspond to the period of decay, and permit a spot to be traced for some time after it ceases to be visible. In other cases the invisible spot never reaches maturity, which means that the cooling produced by expansion never becomes great enough to produce perceptible darkening of the sun's disk.

TWINS AGAIN

THE popular interest in twins seems to have considerable vitality. Every year brings into the public press and magazines some news item or article concerning multiple births. Just a year ago the whole country was stirred by the announcement of the birth of quadruplets in New Haven, Connecticut. (By the way, they have all passed their first birthday). Recently the newspapers carried full accounts of the death of the conjoined Blazek twins of Chicago, recalling the older days when the Siamese twins were in the prints and broadsides. Now comes Los Angeles, with photographic evidence that in one school building are enrolled as many as nine pairs of twins. And on the heels of the City of Angels comes the City of Churches, Brooklyn, with a contingent of ten pairs of twins, all attending Public School 77. Some statistician may soon find for us a rural school in which 30 per cent or more of the entire enrollment are twins.

After all, twins are more common than we ordinarily suppose; and our interest in them far exceeds their rarity. Wappeus found that more than one child was born in 1.17 per cent. of 20,000,000 cases of labor. Pre-war Prussian statistics showed that twins occurred once in 89, triplets once in 7,910, and quadruplets once in 371,125 labors. This does not, of course, mean that all survive. The hazards of birth and of both prenatal and neonatal life are greater for plural than for singular pregnancies.

Wide W

TWINS ATTE NG A B KLYN PUBL SCHOOI

A comparison of international statistics appears to indicate that multiple pregnancy is more common in cold than in warm climates. We should, therefore, not be surprised that Brooklyn has a higher record than Los Angeles! If the figures quoted by Williams can be trusted, Russia is in this special sense over twice as prolific as Spain. In Russia, multiple birth occurred once in 41.8 labors, as compared with once in 113.6 labors in Spain.

The accompanying photographs raise some interesting questions in regard to the distribution of sex among twins. In the aggregate 38 children are pictured, of which 18 are boys, and 15 of these happen to be in the California group. This approximates the equal or nearly equal divisions which we should expect when all the twin boys and girls in the land are counted. But there are other interesting questions. Suppose the Brooklyn group were playing helter-skelter in the school yard. Would it be possible for a stranger to select all the pairs of twins and match each to the appropriate co-twin? It happens that there is such a predominance of same-sexed similar twins that this could be readily done. Suppose, however, that the Los Angeles group were scrambled in the same manner, would it be possible by inspection to pair off all the twins? This is doubtful. It would be particularly difficult to make a confident decision in the case of the four children in the back row, beginning with the third from the left. This difficulty brings out clearly the fact that there are marked differences as well as resemblances between twins. We, of course, always expect at least some degree of family resemblance, but even this may not be obvious to ordinary observation.

The problem of twin resemblance is discussed by Dr. Arnold Gesell, professor of child hygiene, Yale University, in two recent articles on "Mental and Physical Correspondence in Twins," published in the April and May numbers of THE SCIENTIFIC MONTHLY. He describes a remarkable case showing extensive, detailed correspondence both in physical and psychological characters in a pair of gifted girl twins He notes, however, that pathological deviation in the process of twinning may produce monstrous degrees of individual difference even in twins derived from a single egg. Biologists recognize two major classes of human twins: (1) Duplicate or uni-oval, who are always of the same sex, closely resemble one another and presumably originate from one fertilized egg All but one of the Brooklyn group apparently belong to this class; (3) Fraternal or bi-oval twins, who may or may not be of the same sex, who show ordinary family resemblance and are in all probability derived from two separate eggs Two pairs, at least, of the Los Angeles twins belong to this category. Statistics based on a large series of cases indicate that one pair of twins in every three pairs born consists of a boy and a girl, and that about two out of every five pairs in which the members are of the same sex are uni-oval in origin. Since there are only two pairs of two sexed or "pigeon" twins in the combined group of 18 pairs in the photographs, we must again be cautious in drawing general deductions from the pictures.

Do resemblances decrease with age? Such a deduction might be drawn from the Los Angeles photograph, but it would not be well supported by the facts. Two pairs of twins of the fraternal type happen to include the older children in this group, and resemblances are less marked in this type. The fundamental correspondences, both physical and mental, to be found in twins unquestionably have a hereditary basis and are only in a secondary way affected by time and experience. Time may, by a cumulative process, accentuate a differentia-

tion of twin personalities dating from childhood or youth, but the primary differences and resemblances are due to original nature. The study of twins does not shake our confidence in the importance of education and surroundings, though it impresses upon us at every turn the decisive significance of inheritance and the lawfulness of the mechanics of development. The popular interest in twins is a wholesome one, because twins are a key to many biological and psychological principles at the basis of human welfare.

SCIENTIFIC ITEMS

WE record with regret the death of Henry Marion Howe, emeritus professor of metallurgy in Columbia University; of John Sandford Shearer, professor of physics at Cornell University; of George Simonds Boulger, the English writer on botany, of Ernest Solvay, known for his process for the manufacture of soda, and of C. L. A. Laveran, of the Pasteur Institute.

AMONG five busts unveiled in the Hall of Fame for Great Americans at New York University on May 20 was one of Maria Mitchell, the gift of her nephew, William Mitchell Kendall, and the work of Emma S. Brigham. President Henry Noble McCracken, of Vassar College, where Miss Mitchell was professor of astronomy from 1865 to 1888, unveiled the bust.

DR. RAY LYMAN WILBUR, president of Stanford University, has been elected president of the American Medical Association for the meeting to be held next year at San Francisco.

THE Croonian lecture was delivered before the Royal Society on June 1, by Dr. T. H. Morgan, professor of experimental zoology in Columbia University. His subject was "The mechanism of heredity."

DR. W. W. CAMPBELL, director of the Lick Observatory, has been elected president of the International Astronomical Union in succession to M. Baillaud, director of the Paris Observatory. The Astronomical Union held its triennial meeting in Rome in May and will hold its next meeting in Cambridge, England.

IT is announced that the contest of the will of Amos F. Eno will be settled out of court by the payment of about four million dollars to Columbia University. The 1915 will, which has been twice broken by juries but both times upheld by courts on appeal, gave the residuary estate to Columbia University. The will made bequests of $250,000 each to the Metropolitan Museum of Art, the American Museum of Natural History, the New York Association for Improving the Condition of the Poor, and the New York University. Had the will been broken finally, these institutions would have received nothing. Whether they receive the full $250,000 each under the settlement, or what proportion of the total they receive, is not disclosed. The Society of Mechanics and Tradesmen received $1,800,000 under the 1915 will, and had that will been broken would have received $2,000,000 under an earlier will. This institution could not therefore be called upon to sacrifice anything in order to satisfy the heirs, and will receive the full $1,800,000.

WE much regret that there was an error in the inscriptions of the illustrations of the note on *Hesperopithecus* in the last issue of this journal. Fig. 2 on page 589 is the important type tooth, whereas Fig. 1 is the second molar of *Hesperopithecus* which serves to confirm the first of the type.

THE SCIENTIFIC MONTHLY

AUGUST, 1922

THE GEOLOGIC EVIDENCE OF EVOLUTION

By Professor EDWARD W. BERRY
THE JOHNS HOPKINS UNIVERSITY

ONE of the outstanding, possibly the only difference between man and the other animals is his ability to profit by the experience and accumulated wisdom of the race, and yet, despite this characteristic, each generation seems to produce its quota of anti-vaccinationists, anti-evolutionists and believers in a flat earth. We may still entertain the hope that the race is becoming more rational when we recall that it has taken about three centuries to convince the Anglo-Saxon and a few other races among the countless millions of the globe that the earth is not flat, so that to-day only the leader of Zion City (Voliva) among leading cosmologists defends the pentateuchal view.

I do not wish to be thought of as sneering at any one's beliefs, and I fully realize that there are a great many earnest Christian men and women who are perturbed at anything that they think, rightly or wrongly, will shake the foundations of their faith, who are puzzled by the present outspoken opposition to evolution, and who wish to know what is the truth. No truer article of faith was ever penned than the motto of the Johns Hopkins University—*Veritas vos liberabit*—and to you seekers after truth I would like to explain away certain misconceptions, before undertaking to show you that the record of earth history is the record of evolution, and not to be disputed by honest people.

Evolution is not a theory of origins, nor an article of scientific faith, but an indisputable fact. We could not teach geology without teaching evolution. One of the difficulties to the layman is the confusion of evolution—the record of the past and present history of organisms—with the various theories that have been proposed to explain its factors or mode of operation. Let me emphasize that evolution, the record, is in an altogether different category from the theories such as Darwinism, Lamarckianism, or any other

ism that has been advanced to explain its working. You may flout all the theories or you may advocate one of a dozen different theories, but this has nothing to do with the history of life. We, in geology, spend much time in going over the history of organisms, but pay but slight attention to the theories—at least in our teaching.

A simple illustration of the once universal and now fortunately less frequent clerical reaction to evolution will make clear what I am driving at. Evolution was regarded as a dangerous heresy, inimical to Christianity, contrary to Genesis, which was regarded as a scientific account of the origin of the earth and its inhabitants. Do these people claim that the hundreds of varieties of horses, dogs, chickens and pigeons go back to the Garden of Eden, or were in Noah's ark, or that all the horticultural varieties of flowers, shrubs and vegetables were in Mother Eve's kitchen garden? *Not at all!* They are more or less familiar with the cattle breeders or the Burbank method of artificial selection. Their objection to evolution rests on the assumption that man is of a different stuff from the brute world—as if they had had no experience with congregations or legislative assemblies. It is the implied collateral relationship with monkeys, and the tradition engendered by medieval art that the devil has a tail that offends their dignity.

The statement that the human species is descended from monkeys is merely polemical obscurantism and the playing on prejudices that started with Bishop Wilberforce—soapy Sam as he was called by some of his contemporaries—and is a sort of Bryanesque smoke screen. As to lineage, man is not at all closely related to the existing monkeys or apes. They are the culmination of different lines of evolution, and this statement is especially true of the monkeys. That their ancestry in the far distant past approximated the human line or indeed may have merged with it millions of years ago in early Tertiary times is quite another matter.

I find nothing in Genesis either for or against evolution. The language, to be sure, is not explicit (dust of the earth), but the special creation of man as opposed to the evolutionary creation is entirely an egoistical interpretation that is supposed, quite wrongly it seems to me, to add dignity to ourselves, and is of a cloth with the idea that the earth is the center of the universe—all the earth (homocentric) centering in man, and all the universe revolving around the earth—man's temporary abode. It is a most curious revelation in the workings of the human mind that so many good people grow indignant over the idea that man was made from a long line of animal ancestry as degrading; and yet who do not

quarrel with the facts that each human starts his or her individual life as a single cell, and during the nine months preceding birth passes through a series of stages that roughly epitomize the main stages of evolution, even to possessing a rudimentary tail like an ape. Five hundred years ago we should have said that embryology was the invention of the devil to test the faith of the elect—exactly a reason that was once advanced to explain the fossils in the rocks. To-day most of us know better, and we find in the truth of creation far more to reverence than in the anthropomorphic deity of the childhood of the races.

In approaching the geological record of evolution, I will state only facts and leave fundamental causes severely alone. The mechanism of evolution we leave to experimental biology, and I do not advocate any theories of explanation. Here is evolution. Here are the myriad of forms that moved across the stage of the past and were the actors in the drama of life. In geology, to borrow a simile from written history or philology, we are dealing with the original documents in so far as they were preserved as fossils, and in their actual order of succession.

In approaching the geological record, the time conception is most important, and I can best illustrate this by a brief recital of the progress of knowledge concerning fossils. It is only in comparatively modern times that fossils have been recognized as the remains of animals and plants that had once been alive. The early Greeks were sane enough to recognize this apparently obvious relationship, and we find Xenophanes, 500 B. C., speculating on the fossils found in the quarries of Syracuse, Sicily. But during the middle ages there was no end to the discussion regarding the nature and origin of fossils. What seems strange in this year of grace may really not have been so strange in the days when the universally held belief was that of spontaneous generation, a flat earth created in six days, and the only past submergence of the land that of Noah's flood. Was it not the same "plastic force" in nature which traced the frost patterns and the moss agate that fashioned the fossils, and was there not every gradation from shells and bones that exactly resemble recent ones to mere stones of similar form and appearance? We now know that the mineral replaces the organic matter of a fossil. Was it strange to have believed three or four hundred years ago that the process was the reverse—from the mineral toward the organic? At any rate many strange theories were evolved to explain the fossils. One tells us that fossil shells were formed on the hills by the influence of the stars. Others called up a stone-making spirit. Others believed that fossils were the models made by the Creator in perfecting his handiwork before

he essayed the task of making living organisms. I am quoting entirely the views of devout churchmen. Others believed that fossils were mere "figured stones," or were the abortive products of the germs of animals and plants that had lost their way in the earth, or that they were the invention of the devil to test the faith. Even after the belief that fossils were the remains of animals and plants had become well established, it was assumed that they had been killed by Noah's flood and stranded on the mountain tops—an interpretation suggested by Martin Luther in 1539 as secular proof of the correctness of the scriptural account. This flood theory found numerous advocates throughout the seventeenth and even far into the eighteenth century. It passed through various phases of opinion. At first, the fossils were regarded as similar to those still living in the vicinity—a natural enough belief when the universal acceptance of the Mosaic cosmology and a world but 6,000 years old is borne in mind. Later, when the differences in the fossils became apparent, it was assumed that they had been swept to Europe and buried by the waters of the flood and represented forms still existing in the tropics. With the progress of knowledge of tropical organisms this last view became untenable, and it was thought that the fossils represented forms that had been exterminated by the flood, and from this it was but a slight step to the once popular belief that there had been no thistles or weeds or noxious insects in the Garden of Eden, that all creation had become base with the fall of man. Gradually it came to be recognized that fossils were not only frequently unlike recent organisms, but that they were very ancient, and not merely antediluvian, but pre-Adamitic—a view first advocated by Blumenbach in 1790. We are still far from a chronology. Granting that fossils were the traces of once living organisms and antedated Adam—what of it? When Guettard (Jean Etienne Guettard, 1715-1786) made one of the first geological maps, it wasn't really a geological map in the modern sense, but a map of what he called mineral bands (like a modern soil map). He had no idea of geological succession or of structure. The credit of recognizing fossils as the modals of creation we owe to the genius of William Smith (1769-1839) and to the orderly arrangement of the Mesozoic rocks of the English Midlands. Smith journeyed about for years in this region, where the succession of fossiliferous strata is an open book. In his work of building canals, roads and drains, he observed that each bed contained fossils, some of which were peculiar to it, and he found that he could recognize the same horizons and the same succession at many different localities.

This important generalization has since been verified and end-

lessly extended. The contained fossils furnish the surest guides to the age of the sedimentary rocks that geology knows. To the biologist these facts have a deeper meaning, for they show that during the vast lapse of time, to be measured in tens or hundreds of millions of years, the living population of the globe has undergone almost continuous change, old simple forms becoming extinct, and newer, more specialized, forms taking their place, the change being, in general, from lower to higher, in other words—evolution.

That God rested from his six days' task of creation just 4004 years B. C. is so absurd that I have yet to meet a person of normal mind who believes in Archbishop Usher's chronology. There have been many attempts to determine the age of the earth in years—calculations of the rate of cooling of molten bodies, the rate of retardation by tidal friction, the thickness of the sedimentary rocks, the amount of dissolved salts added to the oceans by the rivers of the world, the condition of the radium minerals in igneous rocks. All methods contain unknown variables and are merely estimates. A favorite method has been to measure the thickness of a composite section of the sedimentary rocks, for the whole

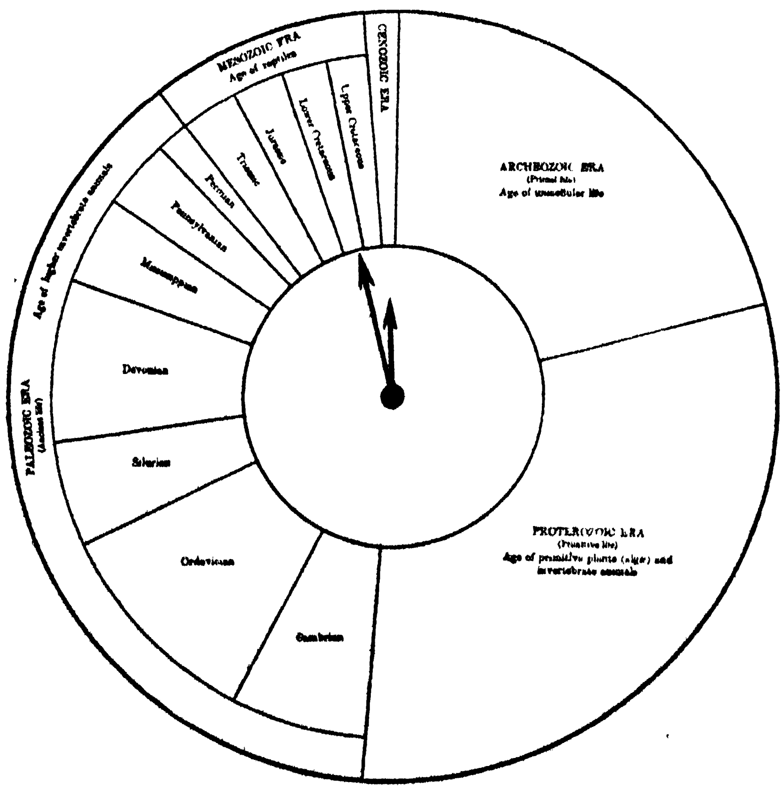


FIG. 1. GEOLOGIC TIME CLOCK

record is not complete in any one section—seas and sediments shifted with the incessant change in geographic pattern. If they had not, we should have such a perfect record of evolution with no missing chapters that we should be able to establish geological time boundaries between rock formations or biological boundaries between animal and plant groups.

The measurement of thicknesses has this advantage, that whereas its results expressed in years are not accurate, its results expressed in relative ratios of duration for the different geological periods are fairly so. I have sought to show the totality of geological time reckoned in this way in the form of the face of a clock in which the dial represents the total thickness of sedimentary rocks divided among the different geological periods in the proper ratios. With this perspective I wish to pass in review in an untechnical way some of the facts of evolution. Obviously, one can not go into details in a brief hour, nor present the links in the chain of evidence, or talk about the septa and sutures of the ammonites, the pygidia of trilobites; or the frontal, parietal, temporal and other bones of the vertebrates.

Show us one species changing into another, and we shall believe in evolution, says the bigot, expecting to see an Alice-through-the-looking-glass transformation of cats into dogs or rabbits into porcupines, not realizing what a species is, or the slowness with which very obvious new characters are acquired as measured in terms of human years. If they had been present through any 70 years of geological time, they would have seen no more evidence of evolution than they see to-day. The first man to see the transformation of species was Waagen,[2] an Austrian geologist and paleontologist, who, in 1869, in the successive layers of fossiliferous Jurassic rocks, observed the minute and inconspicuous changes of form in a definite direction, resulting as they increased in magnitude in the gradual emergence of successive new species of ammonites (Oppelia). These observed grades of difference or nuances (Waagen termed them mutations) are the more gradual and inconspicuous the more abundant the material studied, or the finer our analysis of it. This observed gradual evolution of adaptive characters is quite the opposite of Darwin's theoretical idea of the natural selection of chance variations, and its abundant verification among all groups of fossil organisms wherever an abundance of successive faunas or floras are available for study is one of the reasons why paleontologists have never been strong Darwinists, but

[2] Waagen, Wilhelm Heinrich: Die Formenreihe des Ammonites subradiatus. Versuch einer Paläontologischen Monographie. Geognostisch-Paläontologische Beiträge. Bd. 2, Hft. 2, pp. 179-256, pls. 16-20, November, 1869.

have emphasized the environment as the main stimulus of variation. Discontinuity is observed only in characters where continuity is impossible, as in changes in the number of teeth or vertebra. I could spend days showing you these evolutionary series of trilobites, brachiopods, crinoids, molluscs, etc., but they are not especially convincing without fullness of knowledge and presentation, and are not nearly so impressive to a lay audience as the more obviously discerned, but identical, series among the higher vertebrates. There is probably no group of organisms as ideal for evolutionary studies as are the Ammonites—extinct relatives of the pearly Nautilus. Their shells are preserved in tens of thousands in the Mesozoic and earlier rocks. From the time the embryo formed its first shell until death, each successive stage is preserved in calcite within the enrolled shell. If you would see the size, form and details of ornamentation of a baby, adolescent or mature shell, all you have to do is to break away the outer shell. No other fossils furnish a complete life history with each individual. Moreover, the repetition of phylogeny during ontogeny is beautifully shown, as well as the inheritance of acquired characters, so

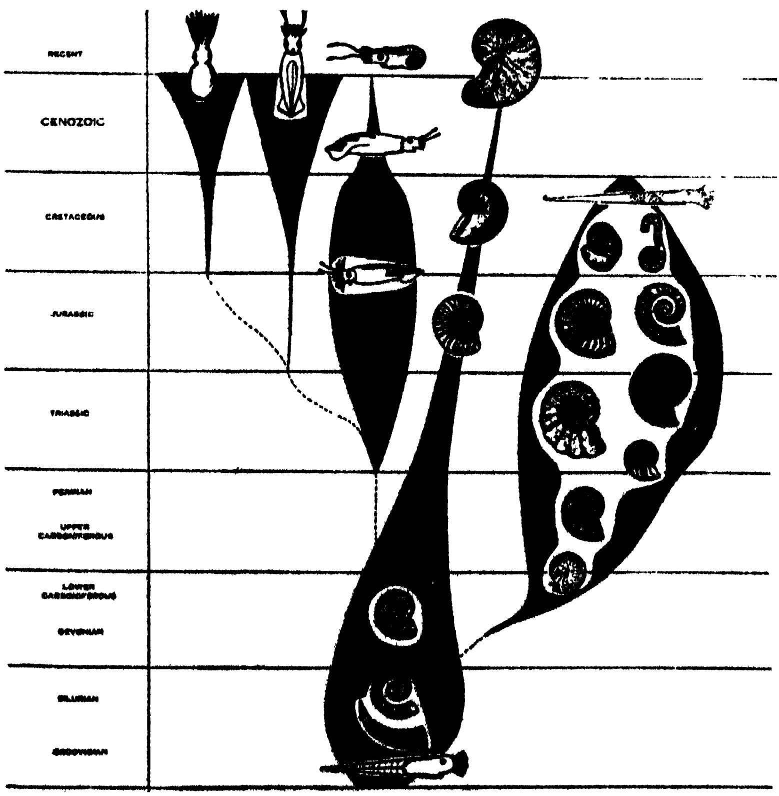


FIG. 2. THE EVOLUTION OF THE CEPHALOD PHYLUM

that we know the ammonite descent much better than we do that of many still existing groups of organisms. The main outlines of the evolution of the Cephalopods, to which group the ammonites belong, is shown in its chronological setting in Figure 2. Observe the gradual transformation of straight camerated shells becoming curved, then loosely coiled, then tightly coiled, giving rise to forms with angulated floors to the living chamber, the parent stock waning with the rise of the daughter stock, and represented to-day by a single living type, the pearly Nautilus. This daughter stock waxing great during Mesozoic times, we know 10,000 different species, gradually reaching overspecialization or racial senility, displayed in the progressive uncoiling and bizarre ornamentation of the shells, and finally passing off the stage altogether. A second main line of descent leads from the ancient Nautilus stock in the direction of animals whose soft parts outgrew their shells, retaining them within the mantle. This second line waxed abundant during Mesozoic time, and then waned in competition with its more perfected progeny, being represented in existing oceans by the single form, Spirula, which in its extreme youth lives in a tiny chambered shell like that of its remote ancestors, but soon outgrows this shell, and for the rest of its life carries this eloquent witness of its ancestry within the hind end of its body. You might remain incredulous before a single Spirula, but when you can trace throughout the records of hundreds of thousands of years the gradual subordination and progressive decrease in relative size of the shell and increase of the soft body, the meaning is unmistakable, and to corroborate the correctness of our reading of history, we have the more modern group of squids and cuttles with all of the morphological features of the Spirula stock, which solved their problem by modifying the now useless shell into an internal axis of support and are otherwise entirely soft bodied and often of large size; and, finally, the latest evolved group—the Octopoda—smaller less active forms, having slight need for the axis of the more elongated and actively swimming squids, have lost all traces of the ancestral shell.

Another great phylum of invertebrate animals (Echinoderma) starfishes, sea urchins and crinoids, have a wonderful abundance of fossil forms and well-ascertained relationships. Their history shows a worm like ancestor developing a plated exoskeleton of many irregular pieces; the progressive reduction in number and the assumption of definite form of these pieces—the radial symmetry impressed by the habit of stalked attachment—the various lines of descent which sought to increase the food gathering mechanism by extending the parts concerned over the test or rais-

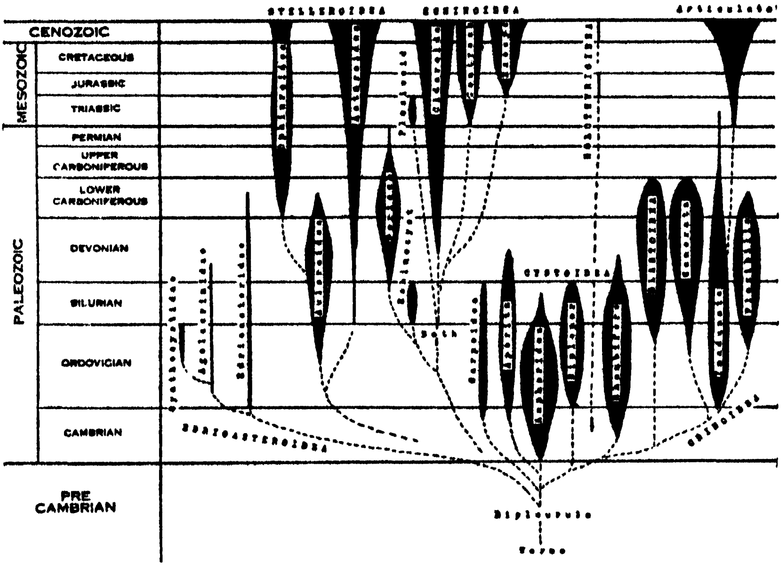


FIG 3. THE EVOLUTION OF THE ECHINODERM PHYLUM

ing them on long arms—the reversed orientation of the errant urchins and starfishes—the one time dominance of specialized crinoids—the late evolution and present abundance of the free-swimming forms with flexible skeletons—the intermediate or synthetic character of the earlier forms, especially well shown in the Ordovician to Lower Carboniferous ancestors of the starfishes and serpent stars—all afford an excellent chapter in nature's record of evolution.

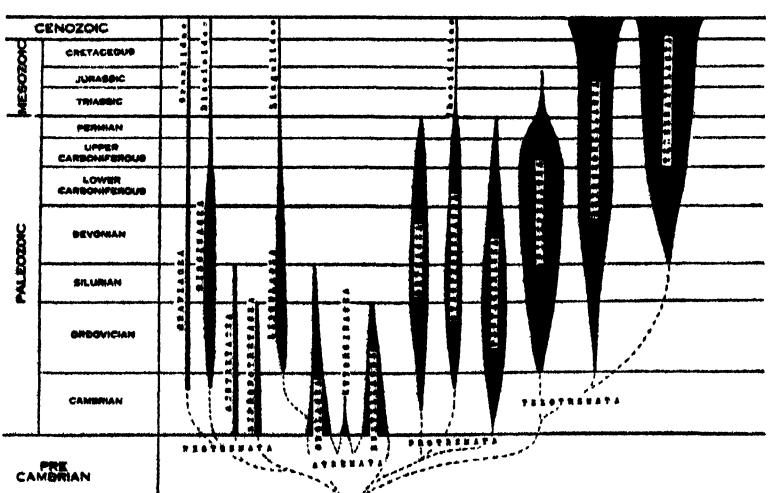


FIG. 4. THE EVOLUTION OF THE BRACHIOPOD PHYLUM

A group of invertebrates unknown to the layman, but immensely important to the paleontologist, whether he be interested merely in chronology or in evolution, is the Brachiopoda—the bivalved lamp shells of the ancients. The stock is very ancient and shows the most intricate series of gradating forms from the ancient hingeless Atremata, long since extinct except for a single family, which in Ordovician times modified its stalk of attachment into a burrowing organ, and from that time to the present has lived on practically unchanged in an unchanging environment of foul mud inimical to higher forms of life, sharing with the similarly reduced representatives of the two other primitive groups a record of unmodified habits or form in an unchanging environment that has enabled them to come down to the present, although all of their early relatives have long since passed off the stage of existence. Contrast the dwindling history of these families as represented by the black of their life lines with the series of forms, each step in whose history we have represented, of those which perfected hinge mechanisms—a protective device, and internal hard parts—loops and spirals for greater efficiency in collecting food and oxygen. We can see these structures grow until at the present time the few unchanged survivors of the more primitive orders are outnumbered fifty to one by the loop-bearing forms which retained the habit of protruding their so-called arms in search of food, whereas the spire-bearing forms that developed along with them in Paleozoic times had their arms fastened to their spiral supports and nonprotrusible, and hence faded out of existence in the earlier half of Mesozoic times.

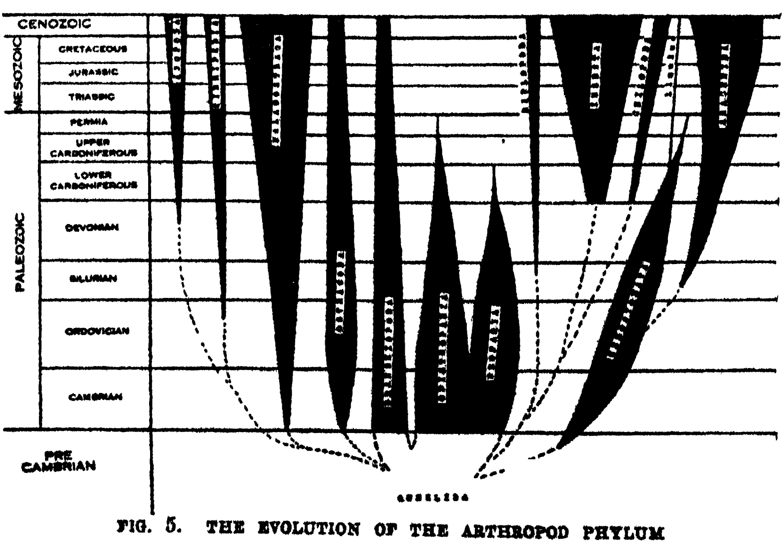


FIG. 5. THE EVOLUTION OF THE ARTHROPOD PHYLUM

A fourth great group is the Arthropoda, embracing the hosts of articulated animals whose relationships are shown, with the early evolution of the aquatic types—trilobites, crustaceans and Limulus-like forms. They exhibit the early efflorescence of the less specialized as to parts, and less protected as to armor—the trilobites; the relative late evolution of their terrestrial descendants—the spiders and centipedes, and the latest appearance of the aerial forms with specialized larval stages—the insects. Most interesting to see displayed among these myriad of diverse forms insects, spiders, crabs and ticks, their community of origin and the impress of their remote trilobite-like ancestry.

Either these myriads of slightly differing forms in progressive or retrogressive series represent evolution, or each slightly changed faunal and floral assemblage represents an independent act of special creation. These are absolutely the only alternatives, and the advocates of special creation, little as they seem to realize it, have to assume a creator, who every few years during a period of hundreds of millions of years mechanically fashioned new sets of organisms. Not only so, but each new set was fashioned surprisingly like their predecessors, sometimes with vestigial, useless or even harmful organs. It seems to me that this only logical application of the special creation hypothesis is a *reductio ad absurdum*, a bare statement of which is sufficient to demonstrate its obvious falsity. I would offer for the religiously inclined Henry Drummond's dictum that evolution was God's method of creation.

The complete epitome of vertebrate evolution showing the range in time and relative abundance deserves a word of comment. I should like the critics of evolution to explain why the most primitive vertebrates appear twice as far back in the record as any of the others, and why the different classes appear in the actual order from the less to the more evolved—from lower to higher—the fish-like amphibians appearing during the Devonian, the reptiles during the Upper Carboniferous, and the two lines to which the latter gave rise, the mammals and birds in the upper Triassic and upper Jurassic, respectively.

Is it not most unfortunate for evolutionary sceptics that the most ancient fossil bird should be one of the best and most spectacular fossils—feathers and all preserved with great fidelity in the fine-grained lithographic stone of Solnhofen—and should represent virtually a modified and partially feathered reptile, 25 per cent. reptile and 75 per cent. bird. About the size of a crow, the head was billess and the jaws were armed with true teeth, the wings had three free-clawed fingers, the tail was long and lizard-like, of 20 vertebræ, with pinnate feathers and not consolidated

with digitate feathers, the hind legs were wide apart and far back, with distinct tibia and fibula as in the reptiles, with the three pelvic bones distinct as in reptiles with no body feathers, the latter on only the wings, legs and tails—with feeble flight and obvious volplaning habits. (Archæopteryx or lizard tailed bird of the upper Jurassic.)

Before taking up man, I have time to consider but two among the many groups of mammals whose history is almost completely known. You doubtless think of elephants in North America only in connection with zoological gardens or circuses, and yet the elephants were a most conspicuous element of the American fauna from the middle Miocene to the end of the Pleistocene, and numerous bones and teeth have been found here in Maryland. They lived in America much longer than has the human race and much longer than the bears which we commonly think of as characteristically American. The elephants were originally immigrants from the old world. They occupy to-day a somewhat isolated position among hoofed mammals and display a curious but readily understandable mixture of specialized and primitive characters. Their specializations are in head and teeth, their conservatism is in body and limbs. To understand their ancestry, we must understand the five or six African and Asian species of the present. Their most obvious feature is the long trunk or proboscis that gives the name Proboscidia to the order. This trunk is simply an elongated nose, although it did not come into existence in the way Kipling relates. Aside from the trunk the tusks mark the elephant. These are simply much modified upper incisor teeth. The dental formula is then $i\frac{1}{0}\ c\frac{0}{0}\ pm\frac{0}{0}\ m\frac{3}{3}$ This is not the whole story of the teeth, however, for, if you examine an elephant's teeth, you will rarely find more than a single immense functional grinder in each jaw ramus—the milk molars, developing serially 1, 2, 3, and followed in turn by the molars 1, 2, 3 during life—the worn ones being pushed forward and out, a contrivance for increasing the elephant's life span, for an animal is only as long lived as its teeth. The mechanics of trunk and tusk support have specialized the head; cranial bones are thickened and lightened, hence the difficulty of shooting an elephant in the brain. The neck is shortened to bring the head weight nearer the withers. The body is long and massive with large shoulder and hip bones. The feet are short and broad with the nail-like hoofs around the edge. Toes are five but not all hoofed (Indian 5 in front, 4 behind; East African 4 in front, 3 behind). Limb adaptations are those common to all heavy animals of other stocks. Most quadrupeds have knee and elbow per-

manently bent. Great weight necessitates the straightening of the limb and individual bones and the shifting of the articular surfaces from an oblique to a right angled position. Weight of tusks causes a shortening and heightening of the skull. Shortening brings the weight arm of the lever nearer the fulcrum at the neck, and heightening lengthens the power arm and affords attachment for the increased musculature. (Modern tusks weighing 239 lbs. each are recorded.) The lengthening of the trunk makes it unnecessary for the mouth to reach the ground for food and water.

The earliest known fossil elephant, only a potential elephant, was of upper Eocene age and comes from near Lake Moeris in the Fayûm, and was consequently christened Moeritherium. It was small and somewhat suggestive of a tapir. The skull was long and narrow, the trunk was merely a snout, the neck was moderately long and the limbs were slender. The teeth were the most significant feature. Formula $i\frac{3}{2}\ c\frac{1}{0}\ pm\frac{3}{3}\ m\frac{3}{3}$ First upper incisor was small and simple, the second was a downwardly directed small tusk. The third and the canine were non-functional and there were 6 grinders, simple and quadritubercular (4 cusps and 2 crests). In the lower jaw the incisors were procumbent. The first long, the second an enamelled tusk with worn chisel edge; the third and canine already gone and 6 grinders. The second stage of elephant evolution was Palæomastodon of the lower Oligocene of the same region. Several species are known, ranging in size from that of a modern tapir to a half grown Indian elephant. Tooth formula $i\frac{1}{1}\ c\frac{0}{0}\ pm\frac{3}{2}\ m\frac{3}{3}$ canines have gone; the incisors are reduced to a single tusk in each jaw ramus, *i. e.*, two upper and two lower tusks. All the grinders are functional, but they have increased in complexity and now consist of six cusps and three crests. The trunk was still short, the head still long and narrow, the limbs heavier, but still relatively light. The elephants now spread into southern Asia and over Europe during the lower Miocene, giving rise to various collateral lines of evolution along their different routes of dispersal. They increased greatly in size and became more elephantine in appearance. They reached North America during the middle Miocene, and these four-tusked forms spread from Nebraska to Florida. The old-world stock shortened the chin and lost the lower pair of tusks during the Pliocene, giving rise to the mastodons and mammoths of the late Pliocene and Pleistocene, which reinvaded North America and ranged southward to the straits of Magellan. Our mastodon survived much later than the European mastodon, and the males sometimes show vestigial tusks in the lower jaw. The mammoth was the contempo-

rary of early man in Europe as the many excellent carvings of the stone age show, and probably also in North America, as somewhat vaguely pictured carved bone and associated flints indicate. They were so common over the northern hemisphere at that time that we have records of 1,635 fossil tusks, averaging 150 lbs., being exported from Siberia in a single year. Between 1820 and 1833, trawlers out of Happisburg, Norfolk, dredged 2,000 elephant molars from the submerged old land of the North Sea. (We had three true elephants in America during the Pleistocene—the Northern or Hairy Mammoth, the Southern or Columbian Mammoth, and the Imperial Mammoth, the latter standing 13 feet at the shoulder.)

The family tree of our noblest of domesticated animals—the horse—has been called the example *de luxe* of evolution, since no animal stock is more completely known or has a more spectacular history. Long domesticated the modern animal is found almost everywhere that man can live, and of many breeds. As wild animals, horses are found only in the Old World in modern times—the arid plains of Central Asia and Africa. There are several species—horses, asses, zebras and quaggas—very uniform in tooth and skeletal characters, but strikingly different in appearance, because of the superficial difference in coloration and in the development of forelock, mane, tail and ears. They differ from all living animals in having a single toe on each foot. Their remotest ancestors were small five-toed plantigrade animals as were all of the earliest mammals. Hosts of fossil species are known, some extinct side lines especially adapted to certain environments, like the small mountain horses or the forest-dwelling and softer ground-inhabiting forms. Others were a part of the progressive line. The earliest known fossil horse you would not recognize as a horse. How do we know it was? By tracing backward step by step from the known. Nearly every stage of this ancestry is now complete, and we are as certain of the remote Tertiary form as we are of the present cart horse. The earliest well-known ancestral horse is the tiny Eohippus or Dawn horse of our early Eocene. It was about the size of a fox terrier, *i. e.*, 11 to 14 inches high, with a short neck, long body, arched back, short legs and small teeth. The front feet had 4 functional toes, and a splint representing the first or thumb. The hind feet had 3 functional and 2 splints representing the first and fifth. It is significant that at that time the ancestral horse line is so generalized that a layman could not distinguish it from the contemporaneous ancestral rhinoceroses or tapirs.

The second-stage Protorohippus of the middle Eocene was

about the size and proportions of a whippet hound. The thumb splint had now disappeared from the front foot, and the little finger splint from the hind foot. The weight was beginning to center on the middle toe, but it required two or three million years more to completely suppress the lateral toes. If there were time, we might pass in review each stage of horse evolution—the Epihippus of the upper Eocene, the Mesohippus of the Oligocene, about the size of a sheep, the Miocene, Protohippus, Pliohippus, Neohipparion, etc. The upper Miocene Protohippus is in the direct line and may be briefly characterized. About 40 inches high, longer head, longer teeth, deeper jaws, shortened body, longer legs and feet, only the third toe normally reaching the ground, but the second and fourth were complete "dew claws" and helped to support the weight on soft ground. There were many varieties of three-toed horses, and in the late Tertiary they had spread pretty well over the world, being found in South America, Europe and Asia, as well as in North America. By Pleistocene time the horses had become monodactyl, varied, abundant and wide ranging. So countless were the herds that the Sheridan formation of the West was long known as the Equus beds from the abundance of their fossil remains. When, however, America was discovered, horses had become extinct in the western hemisphere as well as in native tradition, although their bones are found associated with flint implements, pottery and fire refuse. They appear to have first been domesticated during the Neolithic, that is about 7000 B. C. in Europe, but probably at a much earlier date in Asia. Our modern work horse is descended directly from the European Neolithic horse, which was much like the Celtic pony. Descendants of this low-bred primitive race were distributed over Eurasia, where they are still represented by the Norwegian and Mongolian ponies. All the earlier horses of written history belonged to this type. It was improved by importations from Libya—the Arabs, for example, getting stallions and brood mares from Barbary, where the stock had suffered no ill effects during the Pleistocene glaciation, there having been no severity of climate in northern Africa. The course of evolution in the horses was not confined to the feet. It may be summarized as follows:

Along with the disappearance of side toes went increase in length of leg and foot, especially the distal portion. Increased length of the lower leg and foot increased length of stride and, as the chief muscles are in the upper leg, the center of gravity was changed very little, consequently the swing was about as rapid but mechanical strain was greatly increased, so that strengthening at the expense of flexibility by consolidation of the lower leg and

arm bones and conversion of ball and socket into pulley joints (ginglymoid) occurred. Lengthening of limbs for speed in grazing animals necessitates lengthening of the neck. Loss of toes was a hard ground adaptation for speed. The lengthening of the teeth which caused the deepening of the jaws was an adaptation for hard food and ensured more thorough mastication and a longer life span. Increase in size, although demanding an increased food supply, is a better defence against enemies or competitors. The evolution of the horse was from forest and swamp to grassy plains and went hand in hand with the evolution of the environment. Since monkeys are unaccountably not fashionable and we are very fond of horses here in Maryland, I show you for comparison a skeleton of a modern horse and man. Not only in the structure of all his physical parts, bone for bone, muscle for muscle, and nerve for nerve, is man fundamentally like the other mammals, but his specific organic functions are identical. We have the same diseases; we are similarly affected by the same drugs—in fact the whole wonderful advance of physiology and experimental medicine is built up on this truism. Have you ever thought of the countless generations of meat-eating humans involved in the specialization of the two human tape worms—the one passing its intermediate stage in beef and the other in pork and of which man alone is the host of the adult stage. The pre-humans were not meat-eaters, and we should not fail to take into account the improvement in nutrition in shortening the digestive processes and the stimulating properties of the proteins and their split products that a change in diet gave our ancestors the energy for other things.

I have already mentioned the remoteness of man's relationship with the existing monkeys and apes. Unfortunately, we have but slight knowledge of the earlier stages which remain hidden in the unexplored regions of Asia and Africa, to which much evidence points as the original homes of a majority of the mammalian stocks that appeared in Europe and North America during the Tertiary. But we know much of our less remote fossil ancestors. Evidences of their slowly advancing skill in the fashioning of weapons and implements, in the discovery of the bow and the uses of fire are innumerable, and their skeletal remains are found over a period estimated at from 250,000 to over a million years. We know at least two, perhaps three extinct genera of men and at least five distinct human species. All the existing races of man—white, black, red and yellow—belong to the single zoological species which we modestly call *Homo sapiens*. I should say that our knowledge of the exact stages between non-human ape-like animals and man is as complete as was the knowledge of the evolution of the horse

at the time of the founding of this university when Huxley lectured on the evolution of the horse. At the present rate of discovery (Piltdown man in 1911, Foxhall man in 1919 and Broken Hill man in 1920), another generation will not pass before the story is complete.

Before relating what we now know of this story, I should like to refer to how we arrive at estimates of age in this part of the geological column—estimates which are as exact as the earlier dates of what is called the historic period. During geologic time immediately preceding the present there is conclusive evidence of a mantle of ice spreading over northwestern Europe and northern North America. This was not a single episode but a long enduring succession of glacial stages and milder interglacial stages—some of which were much longer than the time that has elapsed since the last ice sheet shrunk away from the Baltic or from the valley of the St. Lawrence. Naturally the deposits and moraines of the last ice sheet are fresher and less disturbed than the similar traces of the earlier ice sheets. By counting the annual layers in the clays in the wake of the shrinking ice of the last glaciation, we can trace and date its gradual withdrawal from the plains of Germany across the Baltic to the Scandinavian uplands, and the more broken clay layers in the valleys of the Connecticut, Hudson and Champlain give the story for this country. Using this period of time as a unit, we calculate from a variety of criteria the duration of the earlier glacial and interglacial stages. The oldest known man-like animal comes from distant Java and dates from the beginning of the Pleistocene, or from 250,000 to 1,000,000 years ago, or more precisely, twenty-five times as long ago as the interval since the last ice sheet extended across Long and Staten Islands here in the eastern United States. Evidence of human, or if you prefer so to call it, pre-human, industry in the form of rudely chipped flints and a knowledge of fire occur still earlier, and if the recent discovery of the Foxhall man in East Anglia is properly dated, we shall have unmistakable evidence of man in the late Pliocene. Our knowledge of the ape man of Java is on a sounder footing. First of all, he came from Asia along with the greater part of the considerable variety of animals and plants that are found fossil with him. The motive power was the less hospitable climates in Asia resulting from the gradual uplifting of its great mountain areas in the late Tertiary. The fauna and flora including the ape man drifted to the southeast down the broad valleys that at that time of emergence made a single land mass of the Malayan region. The anatomical features of the ape man are technical. Our interest centers on the brain case and the fact that

he was a ground inhabiting biped and not arboreal. The cranial capacity has been variously estimated between 850 and 950 cc as compared with 1,300 to 1,700 of the Neanderthal man of the third Interglacial period, or 650 cc, the greatest ape brain in the gorilla, which has twice the body weight of a man. The lower frontal-lobe region of this brain case shows conclusively that Pithecanthropus possessed speech—not sounds or signals expressive of emotional states, but that he was capable of transmitting ideas and information. In the painstaking models of McGregor, he has managed to superimpose on the obvious inheritance of the brute a look of fleeting intelligence and a dumb prophetic gaze that gives promise of the great things of the then far off future, and I confess to feeling a more tremendous thrill in the contemplation of that empty brain case than any other fossil has invoked.

A long gap in the record brings us to Sussex, England, and Eoanthropus or Dawn man of Piltdown. Discovered in 1911 the usual ignorance resulted in the destruction of most of the skeleton, as it did also in the wonderfully interesting find in the Broken Hill Mine of Rhodesia, so that only a few fragments of skull, 3 teeth, and a portion of the jaw were saved. Subsequently more fragments of other individuals have rewarded the most patient and painstaking search. If there is a wise Providence overhanging the world it is certainly watching over the paleontologists instead of their critics, which is rather surprising if paleontologists are as bad as they are sometimes painted, for these later finds are exactly the pieces needed to supplement the earlier, and to justify Smith Woodward's conclusions. The Piltdown man probably lived during the long and warm second Interglacial period. With him are found very primitive worked flints of the type known as pre-Chellean, together with bones of the rhinoceros, hippopotamus, beaver and deer. The skull is about twice as thick as a modern and 50 per cent. thicker than a Neanderthal skull. Its capacity was about 1,300cc. The jaws are protruding, the chin receding, the nose flattened and the canine teeth very prominent; in fact, although the skull and brain are essentially human and denote the power of speech, the jaws and teeth are much like those of a young chimpanzee, as are certain muscular attachments of the neck and temporal regions.

About the same age as the Piltdown man is the so-called Heidelberg man, based on a single jaw found in 1907 associated with a large fauna at the base of the Mauer sands, 79 feet below the surface. This jaw is exceedingly massive with receding chin, but human dentition, and is generally regarded as merely an extinct species *Homo heidelbergensis,* although some students would erect a distinct genus, Paleonthropus, for its reception. It seems clearly

to foreshadow the Neanderthal race of the third Interglacial period. Passing over implements representing the evolution of human industry and confining our attention to actual human bones, we must now jump from the time of the Piltdown and Heidelberg men over a blank interval, estimated at from one to two hundred thousand years, to the Neanderthal race. I say race advisedly, because some hostile critics have waxed humorous or satirical over the type skull-cap found in the Neander valley near Düsseldorf, as if that were the whole story. The earliest find of this race was a female skull found at Gibraltar in a cave in 1848, but the significance of which was not recognized until 1887. The Neander skull-cap with thigh bones and other fragments was discovered in 1856, and their description was received with indifference even by Darwin and Huxley, and it was not until a generation later, when two complete skeletons were found at Spy near Dinant in Belgium, 1887, that recognition of their significance became general. The appearance of this race in western Europe was contemporaneous with the wane of the last warm forest and meadow fauna of the Pleistocene and with the invasion of animals heralding the approach of the fourth glaciation. Hence the Neanderthal race dwelt in caves. Wells writes picturesquely, but not especially accurately, of their jackal-like habits, but the Neanderthalers were hardy, and appear to have utilized the bison, wild cattle, horse and deer for food, ousting cave bear and cave hyenas—the successive layers in the caves often tell an eloquent story of the struggles between man and beast for possession. Fire played its part and old hearths are abundantly preserved. Spears and throwing stones appear to have been the weapons used. The abundance of skeletons of this race is due to their cave habit and hence their better chance for preservation. Over an interval of something like 50,000 years, if not much longer, preceding Neanderthal times, we have abundant evidence of human industry in the pre-Chellean and Chellean cultures represented by flint implements, but these open-air nomads either threw their dead to the hyenas or buried them in the river terraces on which they dwelt, where the chances of preservation and fossilization were remote.

Homo neanderthalensis, primigenius or *mousteriensis* as it has been called, has been discovered at over twenty different localities. Skeletons of men, women and children and of many individuals have been collected, so that the earlier critics of the type material who pronounced them merely pathological, *i. e.*, a diseased modern man, are completely and absolutely refuted. In many of their important features this race was more ape-like than human, but their teeth were decidedly human; they possessed the power of speech,

fashioned skins and weapons, were skilled in the use of fire, and practised ceremonial burial, placing implements with their dead, the first appearance in the geological record of a belief in a future existence, so that we can not cut them off from us and say they were apes and not men. Let us get a good picture of this race that lived in Europe longer than have the Anglo-Saxons. They were short and thickset—the tallest skeleton indicates a height of 5 feet, 5½ inches; with very broad shoulders and muscular robust torso, big hands, short fingers, and not entirely perfected thumb joints. They were clumsy on foot, with ape-like legs, in that the shin is relatively short and the thigh long (shin 76 per cent. of thigh). Their knees were habitually bent, and they were squatters instead of sitters when resting or working, as shown by the facets on the ankle bone (astragulus). The forearm was relatively short, like the modern Eskimos, Lapps and Bushmen. That they were far removed from contemporary apes is shown by their arms being but 68 per cent. the length of their legs. In apes the reverse prevails—the chimpanzee's arm is 104 per cent the leg length. The position of the foramen magnum, and the neck vertebra indicate stooped shoulders with the head held well forward, and a spinal column curved like that of a modern baby. The head was massive, with deep face, retreating forehead from heavy overhanging brows (platycephalic), with broad flat nose, long upper lip, prognathous jaws and receding chin. The skull was thick, but capacious. The jaw was similar to, but less massive than, that of the Heidelberg man of the second Interglacial. Let me point out that if you should find a modern skull with some of the ape-like features of the Neanderthal skull, it would prove nothing. Some of these ape-like features do occur in recent rare individuals of the lower races—they are all present in the Neanderthal skulls that have been discovered. I have said that the skull was capacious—the limits of variation are 1,300 to 1,700 cc (existing man, 950 to 2,020 cc). The size of the Neanderthal brain was therefore entirely human, but I need not emphasize that a large head does not necessarily offer anything except a field for tonsorial art, and what critics fail to take into account is that the Neanderthal brain, although it had quantity, lacked quality—its proportions were decidedly different from a modern brain—those parts concerned with the higher faculties were less developed and with simpler convolutions—this is not inference, but is based on the actual configuration of the interior of the brain case (we even know that they were right-handed). Over 50 sites of Neanderthal industry are known in western Europe (see map) and their implements increased in variety and improved in technique as the years passed, but not to any remarkable degree.

Some anthropologists hold that the Neanderthal race is represented by the Brünn and Piedmont races of the upper Paleolithic, others that they were exterminated by the arrival in western Europe of a new race from Asia about 25,000 years ago. This progressive race of *Homo sapiens*, the same species as ourselves, appears to have come from Asia Minor through Tunis into Spain, and perhaps along the northern shores of the Mediterranean as well. Their successive cultures are known as the Aurignacian, Solutrian, Magdalenian and Azilian, and the development of their industry and art has been traced with the most detailed precision. They were hunters, and followed in the trail of the wild ass, Elasmothere, steppe horse and various other Asiatic immigrants. Associated with fourteen Cro Magnons skeletons in the Grotto on the Riviera near Mentone are two negroid skeletons. (I will not stop to describe this negroid Grimaldi type.) The fourth Glacial period had not yet closed when the Cro-Magnons apeared in Europe, but the climate was dryer—the summer temperate, but the winters severe. Most of the stations where their remains have been discovered were in caves or rock shelters, but several open camps have been discovered, as at Solutré which was probably a summer assembling of hunters. This remarkable race was tall, the average height 6 ft. 1½ inches, with large chest, relatively long legs, remarkable lengthening of the forearm and shin, wide short face, prominent cheek bones, narrow pointed chin, narrow skull, aquiline nose and shallow orbits. They were vigorous and fleet-footed, practiced ceremonial burial, had much improved implements including the bow and arrow and stone lamps, with brains 1,500 to 1,880 cc. They show an appreciation of animals and have been called the Greeks of the old stone age because of their art, which included drawing, engraving, paintings and bas reliefs on cavern walls and floors, and the carving of soapstone, bone and ivory. Their history shows fluctuations in art and industry, in particular their flint workmanship declined with the introduction of bone implements. During the climatic fluctuations concerned with the oscillations of the shrinking glaciers and concomitant geographic changes, both their culture and physical vigor show a decline. Their history covers a period of from 10,000 to 15,000 years, and during this time there probably was some intermixture of other blood. Disharmonic skulls, *i. e.*, broad face and narrow skull, are still found in the Dordogne and at a few other localities and near by is the primitive agglutinative language of the Basques. Some conclude that these represent late survivals of the Cro-Magnon race. They were followed by fishing races and the first broad headed types, the Maglemose culture (possibly Teutonic) around the Baltic, the Mediterranean (known as the Tardenoisian), and

the Alpine (Furfooz Grenelle) along the Danube (painted pebbles). This was from 7,000 to 10,000 years ago, and the so-called Campignian culture of this time is transitional to the Neolithic or New Stone Age of polished stone.

The rest of the history belongs more to Anthropology and Archeology. The Robenhausian culture of the Swiss and other lake dwellings about 7000 B. C. shows permanent dwellings, domestication of animals and cultivation of crops with use of pottery: the Copper Age extended from 3000 to 2000 B. C.; the Bronze Age in Europe from about 2000 to 1000 B. C., in Orient 4000 to 1800 B. C.; the Iron Age (earlier or Hallstatt culture) in Europe from 1000 to 500 B. C., in the Orient from 1800 to 1000; and the latter Iron Age from 500 B. C. to Roman times in Europe.[1]

Note the cumulative rapidity of the advance as compared with slowness of change in earlier stages.

Although very much remains to be discovered we know enough to assure the layman that man has had a long evolutionary history extending over tens if not hundreds of thousands of years. Does this knowledge breed cynicism and irresponsibility. What answer does science give on this point? Since late Paleolithic time, *i. e.*, toward the close of the Old Stone age, 25,000 years ago, man's evolution biologically has been slight and to some extent retrograde. Skull bones and teeth have changed but little. It was during this period of slight physical change that our race has made the most astonishing progress, and the hope is natural that there is no limit to the betterment of the race by the exercise of wisdom, altruism and idealism—the spiritual graces if you choose so to call them.

[1] Figures from Obermaier.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture II. Part 2. Wasps Solitary and Social

Authorities on the classification of the social wasps now divide them into five subfamilies, namely the Stenogastrinæ, which are confined to the Indomalayan and Australian Regions, the Ropalidiinæ, confined to the tropics of the Old World, the Polistinæ, which are cosmopolitan, the Epiponinæ, possibly comprising two independent lines of descent from Eumenes-like and Odynerus-like ancestors respectively and constituting a large group, mostly confined to tropical America, with a few species in the Ethiopian, Endomalayan, Australian and North American regions, and the Vespinæ, which are recorded from all the continents except South America and the greater portion of Africa south of the Sahara. These five families may be briefly characterized before considering some of the peculiarities of social organization common to most or all of them.

(1). The Stenogastrinæ evidently represent a group of great interest, because they form a transition from the solitary to the social wasps, but unfortunately our knowledge of their habits is very incomplete. F. X. Williams has recently published observations on four Philippine species, and though his account is fragmentary, it nevertheless reveals some peculiar conditions. He shows that the single genus of the subfamily, Stenogaster, includes both solitary and social forms and that all of them exhibit a mixture of primitive and specialized traits. The species all live in dark, shady forests and make very delicate, fragile nests with particles of decayed wood or earth. *S. depressigaster* (Figs. 30 E and F) hangs its long, slender, cylindrical nests to a pendent hair-like fungus or fern. The structure consists of tubular, intertwined galleries and cells, with their openings directed downwards. The colony comprises only a few individuals probably the mother wasp and her recently emerged daughters. The eggs are attached to the bottoms of the cells as in all social wasps and the larvæ are fed from day to day with a gelatinous paste, which Williams believes may be of vegetable origin. In the cells the older larvæ and the pupæ hang head downwards. Another social species, *S. vari-*

[1] Lowell Lectures.

pictus, constructs a very different nest, consisting of cells made of sandy mud mixed perhaps with particles of decayed wood and attached side by side in groups to the surfaces of rocks and tree-trunks (Fig. 30 G). In this case also the cell-openings are directed downward. A nest may consist of thirty or more cells in several

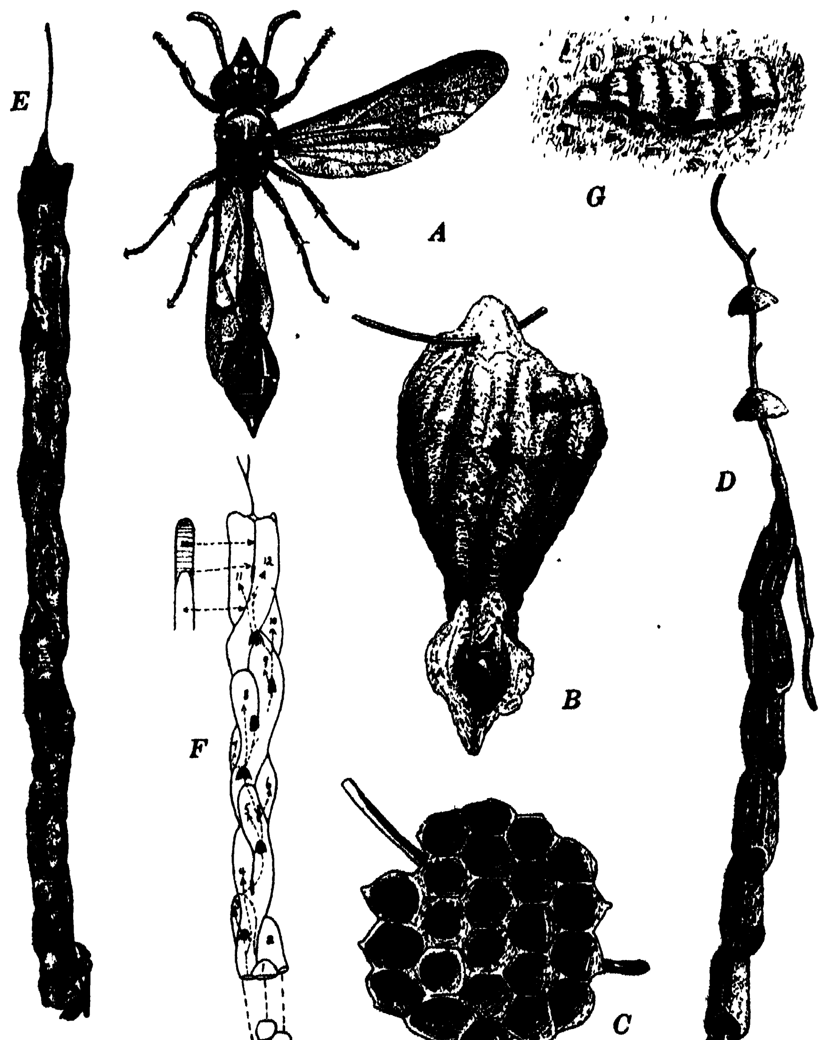

FIG 30
Nests of Stenogastrine wasps from the Philippines. *A*. *Stenogaster micans* var. *luzonensis*, female. *B*. Completed nest of same; *C*. Nest with only the basal portion completed; *D*. Nest of *Stenogaster* sp., with umbrella-like "guards", *E*. Nest of *S. depressigaster*, *F*. diagram of same showing arrangement of cells and passage-ways. The numbers indicate the cells. The tops of the passage-ways are shown in two planes by series of parallel lines. *G*. Nest of *S. varipictus* on the bark of a tree. (After F. X. Williams).

FIG. 31
Suspended and naked comb of a very primitive African Epiponine wasp, *Belonogaster junceus*, with young cells above and old cells containing larvæ below; natural size. Most of the wasps have been removed but two are seen bringing food-pellets to the larvæ. (Photograph by E. Roubaud.)

rows. There are only a few wasps in a colony, and when the larvæ are full-grown the cells are sealed up by the mother as in the solitary wasps. But after the young have emerged the cells may be used again as in many of the social species. Williams describes and figures the nests of two solitary species, one an undetermined form, the other identified as *S. micans* var. *luzonensis*. The nest of the former (Fig. 30 D) is suspended, like that of *depressigaster*, from some thin vegetable fibre and appears to consist of particles of decayed wood. It is a beautiful, elongate structure of seven tubular, ribbed cells, arranged in a zigzag series with their openings below and two peculiar umbrella-like discs around the supporting fibre. These discs "remind one a good deal of the metal plates fastened to the mooring lines of vessels and serving as rat guards. Their function in the case of the nest may be an imperfect protection from the ants, or perhaps they may serve as umbrellas, though neither they nor the cells are strictly rain proof." They may possibly be rudiments of the nest envelopes which are so elaborately

developed in many of the higher social wasps. The mother wasp attends to several young simultaneously, and when their development is completed seals up the cells. *S. micans* var *luzonensis* (Fig. 30 B) makes the most remarkable nest of all. It is attached to some pendent plant filament under an overhanging bank or under masses of dead leaves supported by twigs or vines and is made of "moist and well-decayed wood chewed up into a pulp and formed into delicate paper which is not rain proof." The basal portion of the nest (Fig. 30 C) is a single comb of about 20 regular, hexagonal cells, enclosed in a pear-shaped covering which is longitudinally grooved and ribbed on the outside and constricted below to form a filigree-work, funnel-like aperture surrounded on one side by a spear-shaped expansion. This species seems also to have been observed in Ceylon by E. E. Green, who remarks that "the nest seems to be the property of one pair only" of wasps. Two other species, *S. nigrifrons* of Burma and *melleyi* of Java, are also recorded as social. They make nests consisting of a few pendent, hexagonal-celled combs attached to one another by slender pedicels. All of the descriptions indicate that the colonies of the social species of Stenogaster must consist of very few individuals, and there is nothing to show that the female offspring

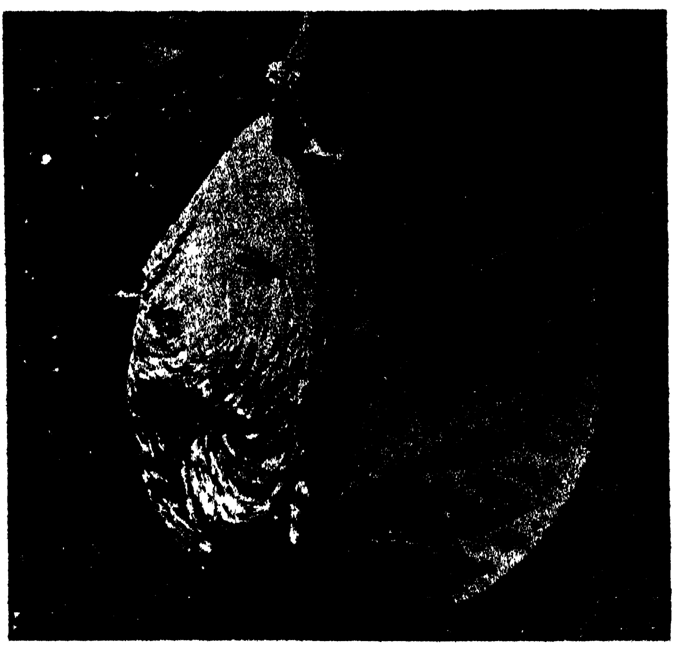

FIG. 32
Nest of *Polybioides tabida* from the Congo, with the involucre partly removed. (After J. Bequaert from a photograph by H. O. Lang).

differ in any way from their mother or that they assist in caring for the brood. Even in the case of *S. varipictus,* Williams remarks: "In a small way, it seems to be a social wasp; one to several insects

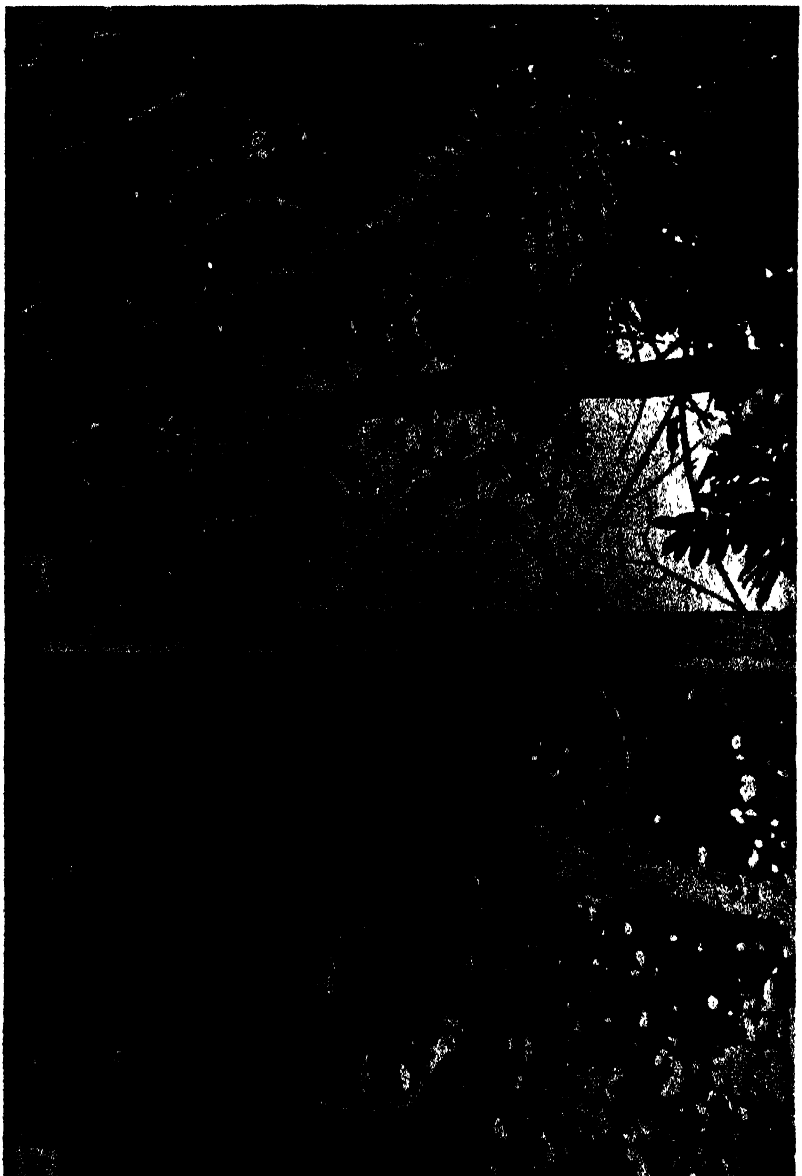

FIG. 33

A. Nest of *Polybioides melaena* of the Congo. *B.* The same partly destroyed, showing the pendent combs, which have cells on both sides. (After J. Bequaert, from a photograph by H. O. Lang).

attend to a cell group. It may be, however, that each female has her own lot of cells in this cell group.'' Future investigations may show that none of the species of Stenogaster is really social in the same sense as are the four other subfamilies, though they approach the definitively social forms in using paper in the construction of the nest, in sometimes making combs of regular hexagonal cells and in caring for a number of larvæ at the same time.

(2). The Epiponinæ are a large and heterogeneous group, comprising a much greater number of genera (23) than any other subfamily of social wasps, and ranging all the way from very primitive forms like Belonogaster to highly specialized forms like Chartergus and Nectarina. Great differences are also apparent in the architecture of the nest, which in the more primitive genera consists of a single naked comb of hexagonal cells attached to some support by a peduncle (Fig. 31), and in the more advanced forms of a single comb or of several combs superimposed on one another and enclosed in an envelope with an opening for ingress and egress (Figs. 32 and 33). The combs are in some cases pedunculate (stelocyttarous), in others attached directly to the support or to the envelope (phragmocyttarous). In nearly all cases the nest is made entirely of paper, but in a few tropical American species some clay may be added. It is always above ground and attached to the branches or leaves of trees, to the underside of some shelter (roofs, banks, etc.). In primitive forms like Belonogaster (Fig. 31), as a rule, a single fecundated female starts the nest by building a single pedunculate cell and then gradually adding others in circles concentrically to its periphery as the comb grows, but not infrequently the foundress may be joined by other females before the work has progressed very far. Each larva is fed with pellets of malaxated caterpillars till it is full grown when it spins a convex cap over the orifice of its cell and pupates. The emerging females are all like the mother in possessing well-developed ovaries and in being capable of fecundation. In other words, all the females of the colony are physiologically equal, and even such differences in stature as they may exhibit have no relation to fertility. The colonies are small, the nests having usually only about 50 to 60 cells, rarely as many as 200 to 300. In larger colonies there is a certain rude division of labor since the older females devote themselves to egg-laying, the younger to foraging for food and nest materials and the recently emerged individuals to feeding the larvæ and caring for the nest. The males, too, remain on the comb, but behave like parasites and exact food whenever it is brought in by the foraging females. Belonogaster is described as a polygynous wasp because each of its colonies contains a number

of fecundated females. When it has reached its full development the females leave in small companies and found new nests either singly or together. This phenomenon is known as "swarming" and occurs only in the wasps of the tropics where it seems to be an adaptation to the favorable climatic conditions. In the higher South American genera of Epiponinæ, however, the females are not all alike but are differentiated into true females, or queens, *i. e.*, individuals with well-developed ovaries and capable of fecundation, and workers, *i. e.*, females with imperfectly developed ovaries and therefore sterile or capable only of laying unfertilized, male-producing eggs. Many of these wasps, according to H. and R. von Ihering and Ducke, are polygynous and regularly form new colonies and nests by sending off swarms of workers with one or two dozen queens. The colonies often become extremely populous and comprise hundreds or even thousands of individuals. Some of the species (Nectarina, Polybia) have a habit of storing a considerable amount of honey in their combs, while others are known to capture, kill and store within the nest envelope, and even in the combs, quantities of male and female termites or male ants as a supply of food to be drawn on when needed.

(3). The Ropalidiinæ are a small group of only three genera, the best known of which is Ropalidia. These are primitive wasps which build a single naked comb like that of Belonogaster and feed their young with pellets of malaxated insects. The colonies are small and polygynous, but, according to Roubaud, true workers can be distinguished, though they are few in number compared with the true females. Swarming seems to occur in some species.

(4). The Polistinæ are represented by only two genera One of these, Polistes, is cosmopolitan and, like Ropalidia and Belonogaster, makes a single, naked comb, suspended by a central or eccentric peduncle to the underside of some shelter. As there are several common species in Europe and the United States, the habits of the genus are well known. The nest is usually established and in its incipient stages constructed by a single female, or queen. A certain number of her offspring are workers though they seem often to lay male-producing eggs. True females are rather numerous in the colonies of some species, which may therefore be regarded as polygynous, and some of the tropical forms may, perhaps, swarm. In temperate regions, however, the Polistes colony is an annual development and usually not very populous. The young females are fecundated in the late summer and pass the winter hidden away under bark or in the crevices of walls, whence they emerge in the spring to found new colonies. Several of the species, even in temperate regions, are known to store small quantities of honey in their combs.

(5). Like the Polistinæ, the subfamily Vespinæ includes only two genera, Vespa and Provespa. The species of the former, the only genus besides Polistes that occurs in the north temperate zone, are the largest and most typical of social wasps. So far as known the species are strictly monogynous. The nest, founded by a single female, consists at first of a small pendent comb, like that of Polistes, but while there are still only a few cells a more or less spherical envelope is built around it. The eggs first laid produce workers, which are much smaller than the mother and incapable of fecundation. They remain with the parent, enlarge the comb and envelope and, to accommodate the rapidly increasing brood, build additional combs in a series from above downward, each new comb being supported by one or more peduncles attached to the comb above it (stelocyttarous). At first large numbers of workers are produced, but later in the summer males and females appear. Owing to the greater size of the females, the cells in which they are reared are considerably larger than the worker cells. After the mating of the males and females the colony perishes, with the exception of the fecundated females, which hibernate like the females of Polistes and during the following spring found new colonies. In the Vespinæ, therefore, a very distinct worker caste has been developed, though its members occasionally and perhaps regularly lay male-producing eggs. The species of Vespa are usually divided into two groups, one with long, the other with very short cheeks. In Europe and North America the long-cheeked forms as a rule build aerial nests above ground, the short-cheeked forms in cavities which they excavate in the ground. The colonies may often be very populous by the end of the summer (3,000 to 5,000 individuals).

After this hasty sketch of the five subfamilies of the social wasps we may consider a few of their fundamental behavioristic peculiarities, especially the trophic relations between the adults and larvæ, the origin of the worker caste, its ultimate fate in certain parasitic species and the question of monogyny and polygyny. In all these phenomena we are concerned with effects of the food-supply and therefore of the external environment.

The feeding of the larvæ by Vespa and Polistes queens and workers with pellets made of malaxated portions of caterpillars, flies or other insects has often been described and can be readily witnessed in any colony kept in the laboratory. The hungry larvæ protrude their heads with open mouths from the orifices of the cells, like so many nestling birds, and when very hungry may actually scratch on the walls of the cells to attract the attention of the workers or their nurses. The feeding is not, however, a one-sided

affair, since closer observation shows that the wasp larva emits from its mouth drops of sweet saliva which are eagerly imbibed by the nurses. This behavior of the larvæ has been observed in all four subfamilies of the higher wasps by du Buysson, Janet and Roubaud. Du Buysson says that the larvæ of Vespa "secrete from the mouth an abundant liquid. When they are touched the liquid is seen to trickle out. The queen, the workers and the males are very eager for the secretion. They know how to excite the offspring in such a way as to make them furnish the beverage." And Janet was able to prove that the secretion is a product of the salivary or spinning glands and that it flows from an opening at the base of the lower lip. "This product," he says, "is often imbibed by the imagines, especially by the just emerged workers and by the males, which in order to obtain it, gently bite the head of the larva." Most attention has been bestowed on this reciprocal feeding by Roubaud, from whose interesting account of Belonogaster, Ropalidia and Polistes I take the following paragraphs:

"All the larvæ from birth secrete from a projection of the hypopharynx, on the interior surface of the buccal funnel, an abundant salivary liquid, which at the slightest touch spreads over the mouth in a drop. All the adult wasps, males as well as females, are extremely eager for this salivary secretion, the taste of which is slightly sugary. It is easy to observe, especially in Belonogaster, the insistent demand for this larval product and the tactics employed to provoke its secretion.

"As soon as a nurse wasp has distributed her food pellet among the various larvæ, she advances with rapidly vibrating wings to the opening of each cell containing a larva in order to imbibe the salivary drop that flows abundantly from its mouth. The method employed to elicit the secretion is very easily observed. The wing vibrations of the nurse serve as a signal to the larva, which, in order to receive the food, protrudes its head from the orifice of the cell. This simple movement is often accompanied by an immediate flow of saliva. But if the secretion does not appear the wasp seizes the larva's head in her mandibles, draws it toward her and then suddenly jams it back into the cell, into which she then thrusts her head. These movements, involving as they do a stimulation of the borders of the mouth of the larva, compel it to secrete its salivary liquid.

"One may see the females pass back and forth three or four times in front of a lot of larvæ to which they have given nutriment, in order to imbibe the secretion. The insistence with which they perform this operation is such that there is a flagrant disproportion between the quantity of nourishment distributed among the larvæ

by the females and that of the salivary liquid which they receive in return. There is therefore actual exploitation of the larvæ by the nurses.

"The salivary secretion may even be demanded from the larva without a compensatory gift of nourishment, both by the females that have just emerged and by the males during their sojourn in the nest. The latter employ the same tactics as the females in compelling the larvæ to yield their secretion. They demand it especially after they have malaxated an alimentary pellet for themselves, so that there is then no reciprocal exchange of nutritive material.

"It is easy to provoke the secretion of the larvæ artificially. Merely touching the borders of the mouth will bring it about. The forward movement of the larvæ at the cell entrance, causing them to protrude their mouths to receive the food pellet, is also easily induced by vibrations of the air in the neighborhood of the nest. It is only necessary to whistle loudly or emit shrill sounds near a nest of Belonogaster to see all the larvæ protrude their heads to the orifice of the cells. Now it is precisely the vibrations of the air created by the rapid agitation of the bodies of the wasps and repeated beating of their wings that call forth these movements, either at the moment when food is brought or for the purpose of obtaining the buccal secretion which is so eagerly solicited."

Roubaud has called the interchange of food here described "oecotrophobiosis," but for reasons which I cannot stop to discuss, I prefer to use the word "trophallaxis." It will be seen that the larvæ have acquired a very definite meaning for the adult wasps of all the castes and that through trophallaxis very close physiological bonds have been established, which serve to unite all the members of the colony, just as the nutritive blood stream in our bodies binds all the component cells and tissues together. We found that even in forms like *Synagris cornuta* the larva has acquired a meaning for the mother. In this case Roubaud has shown that the mother while malaxating the food-pellet herself imbibes its juices before feeding it to the larva, and that "the internal liquids having partly disappeared during the process of malaxation, the prey is no longer, as it was in the beginning, soft and juicy and full of nutriment for the larva. It is possible, in fact, to observe that the caterpillar *pâté* provided by the *Synagris cornuta* is a coarse paste which has partly lost its liquid constituents. There is no exaggeration in stating that such food would induce in larvæ thus nourished an increase of the salivary secretion in order to compensate for the absence of the liquid in the prey and facilitate its digestion." It is here that the further development to the condition

seen in Belonogaster and other social wasps sets in. The mother finds the saliva of the larva agreeable and a trophallactic relationship is established. As Roubaud says, "the nursing instinct having evolved in the manner here described in the Eumenids, the wasps acquire contact with the buccal secretion of the larva, become acquainted with it and seek to provoke it. Thence naturally follows a tendency to increase the number of larvæ to be reared simultaneously in order at the same time to satisfy the urgency of oviposition and to profit by the greater abundance of the secretion of the larvæ."

As I shall endeavor to show in my account of the ants and termites, trophallaxis is of very general significance in the social life of insects. It seems also to have an important bearing on the development of the worker caste. Both queens and workers arise from fertilized eggs, and the differences between them are commonly attributed to the different amounts of food they are given as larvæ. There seems to be much to support this view in the social wasps. As Roubaud points out in the passages quoted, the larvæ are actually exploited by the adult wasps to the extent of being compelled to furnish them with considerable quantities of salivary secretion, often out of all proportion to the amount of solid food which they receive in return. Owing to this expenditure of substance and the number of larvæ which are reared simultaneously, especially during the earlier stages of colony formation, they are inadequately nourished and have to pupate as rather small individuals, with poorly developed ovaries. Such individ uals therefore become workers. This inhibition of ovarial development, which has been called "alimentary castration," is maintained during the adult life of most workers by the exigencies of the nursing instincts. The workers have to complete and care for the nest, forage for food and distribute most of it among their larval sisters. All this exhausting labor on slender rations tends to keep them sterile. In other words, "nutricial castration" (derived from *nutrix, a nurse,* to use Marchal's terms, takes the place in the adult worker of the alimentary castration to which it was subjected during its larval period. It is only later in the development of the colony, when the number of workers and consequently also the amount of food brought in have considerably increased, and the labor of foraging and nest construction have correspondingly decreased for the individual worker, that the larvæ can be more copiously fed and develop as fertile females, or queens. At that season, too, some of the workers may develop their ovaries, but as the members of the worker caste are incapable of fecundation, they can lay only male-producing eggs. That this is not the

whole explanation of the worker caste will appear when we come to consider the much more extreme conditions in the ants and termites, but it may suffice to explain the conditions in the social wasps and social bees.

Parasitism is another phenomenon which seems to indicate that a meager or insufficient diet is responsible for the development of the worker caste. Although parasitic species are much more numerous among the bees and ants, I will stop to consider very briefly a few of those known to occur among the wasps. A parasite is, of course, an organism that is able to secure abundant nourishment for itself or its offspring by appropriating the food-supply that has been laboriously stored or assimilated by some other organism. The various parasitic solitary wasps, such as the species of Ceropales, among the spider-storing Psammocharidæ, all substitute their own young for the young of their hosts in order that the larvæ may come into undisputed possession of the stored provisions. Among the social wasps there are only two parasitic species, *Vespa austriaca* and *V. arctica.* The former has long been known in Europe where it lives in the nests of *V. rufa.* Recently Bequaert and Sladen have found *austriaca* in the United States, British America and Alaska, but its Cisatlantic host is still unknown, though believed to be *V. consobrina. V. arctica,* as Fletcher, Taylor and I have demonstrated, lives in the nests of our common yellow jacket (*V. diabolica*). Now both *austriaca* and *arctica* have completely lost the worker caste so that they are represented only by males and fertile females. They were at one time undoubtedly nonparasitic like their present hosts, but are now reared and fed by the workers of the latter like their own more favored sexual forms. As a result of such nurture what were once independent social insects with two female forms have actually reverted to the status of solitary forms with only one type of female.

In conclusion the conditions of monogyny and polygyny in the higher social wasps may be briefly considered. It was shown that the Vespinæ and at least most of the Polistinæ are monogynous, their colonies being annual developments begun by a single fecundated queen, and that they perish at the end of the season, with the exception of the annual brood of queens, which after fecundation hibernate and start new colonies during the following spring. Many of the tropical Epiponinæ and Ropalidiinæ, however, are polygynous and the former often form large perennial colonies which from time to time send off swarms consisting of numerous fecundated females or of such females accompanied by workers to found new colonies. This behavior is evidently as perfect an adaptation to the continuously favorable food and temperature condi-

tion of the tropics as is that of Vespa and Polistes to the pronounced seasonal vicissitudes of the temperate regions. There has been a difference of opinion among the authorities as to whether monogyny or polygyny represents the more primitive phylogenetic stage among the social wasps. The great majority of these insects are tropical, and probably even Vespa and Polistes were originally inhabitants of warm regions and invaded temperate Eurasia and North America during postglacial times. The monogyny still exhibited by these wasps in the tropics may have been acquired there as an adaptation to the wet and dry seasons, and this adaptation may have enabled them the more easily to adjust themselves to the warm and cold seasons of more northern regions. H. and R. von Ihering and Roubaud may therefore be right in maintaining that polygyny is the more primitive condition. Their view is also supported by the fact that in the polygynous genera the worker caste is either still absent (Belonogaster) or very feebly developed and constitutes only a small percentage of the female personnel of the colony. We might, perhaps, say that our species of Vespa and Polistes each year produce a swarm of females and workers but that the advent of cold weather destroys the less resistant workers and permits only the dispersed queens to survive and hibernate till the following season.

We shall find precisely the same differences between monogyny and polygyny in the social bees of temperate and tropical regions, and somewhat analogous conditions among the ants, although their polygyny may be secondarily derived from monogyny. It would seem that swarming must be a phenomenon which occurs as a rule when the environment is unfavorable or the colony has grown to such dimensions as to outrun its food-supply so that emigration of portions of its population becomes imperative.

CHARLES DARWIN, THE MAN

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AT the present time, which marks the fortieth anniversary of the death of Charles Darwin (died April 19, 1882), an odd recrudescence of the old opposition to evolutionary thought in the less educated circles is challenging the attention of men of science in this country. But to us it seems much more appropriate to the anniversary to undertake to consider Darwin's personal traits, and especially such aspects of his character as bear upon his far-reaching influence upon men to-day.

Charles Robert Darwin was born in 1809 of a family in which a considerable variety of excellent mental attainments are to be found; a family in which, if we should try to note any single outstanding mental characteristic that found repeated expression, we should have to say that the most constant trait was a very highly developed curiosity. Robert Waring Darwin, his father, was a physician. He was neither scientific nor philosophical in the strict sense, as it is reported that he did not try to generalize his knowledge under general laws. Yet he formed a theory for almost everything which occurred. He is described as having an extraordinary memory for people, events and dates, as being an unusually shrewd judge of character, and also a cautious and good man of business. The grandfather, Erasmus Darwin, showed a speculative turn in his curiosity, and was the author of the afterwards famous Zoonomia. Among more distant relations and ancestors are men who gave their enthusiasm to such subjects as numismatics, statistics and various branches of natural history.

On the maternal side, Darwin had the possibility of inheriting the unusual ability in practical arts for which the Wedgewood family was noted. His mother died early, when the son was only eight years of age, and the published record of her tells little more than that she was of a most kindly and sympathetic nature.

Charles Darwin felt the very deepest of personal devotion to his father, and many of his own traits of character are a very natural development from the family atmosphere in which he was raised. This applies especially to his kindliness and ready appreciation of others, and his extreme modesty as regards his own opinions and

accomplishments. As regards traits that were needed for his future career, it was his opinion that he acquired little besides the love of observing.

School seems to have been of exceptionally slight benefit to the young scientist. In fact the comments upon his education that he makes in his reminiscences are in surprisingly similar tenor to the ironic undercurrent in Henry Adams's reminiscences of his education. He was not taught to observe, nor to think, nor to use the languages which he would need, nor to make serious use of mathematics. To the end of his formal education, his desire seems to have been little more than to escape, usually into the country in company with congenial hunting companions and nature lovers. Strangely enough, this applies even to his life for two years as a medical student in Edinburgh, where he apparently came under a group of lecturers who were uncommonly devoid of inspiration, so that he felt positively repelled even from geology and botany. On the other hand, he began there to make acquaintances who developed his inclination toward acute observation of nature. He names in this connection the zoologist, Grant, and several other young university men, a negro taxidermist, and some of the fisher folk at Newhaven.

As the young Darwin showed only distaste for the medical sciences as presented to him, a church career was proposed instead, and he brushed up on his rusty Greek, to gain admittance to Cambridge. It is interesting that among his studies he found algebra and the classics unutterably dull, but geometry delightful for its vivid and precise logic, and Paley's "Evidences" and "Natural Theology" similarly pleasing for its keen deductive reasoning.

But in the main he shunned his studies in Cambridge as consistently as he had in Edinburgh. He became a devotee of hunting and riding, and then later became deeply engrossed with collecting beetles. "No poet," he says, "ever felt more delighted at seeing his first poem published than I did at seeing in Stephens's Illustrations of British Insects the magic words 'captured by C. Darwin, Esq.' "

Here again, as it had been in Edinburgh, the most important aspect of his life came from the friendships which he formed. Especially noteworthy were his constant companionship with Henslow, the professor of botany, and toward the end of his stay, his acquaintance with Professor Sedgwick of geology.

"Looking back," he says, "I infer that there must have been something in me a little superior to the common run of youths, otherwise the above-mentioned men, so much older than I and higher in academic position, would never have allowed me to asso-

ciate with them. Certainly I was not aware of any such superiority."

Darwin's keen love of good logic and his passion for observation seem not to have been united in the same object in any of his activities in Cambridge, and the thought that they might conceivably be so united seems first to have been brought to him by a conversation with the geologist Sedgwick in the summer of 1831 (Life, p. 48): He told Sedgwick of a certain tropical volute shell that was supposed to have been found in an old gravel pit near Shrewsbury, England. "He at once said that it must have been thrown away by some one into the pit; but then added, if really embedded there it would be the greatest misfortune to geology, as it would overthrow all that we know about the superficial deposits of the Midland Counties. . . . I was . . . utterly astonished at Sedgwick not being delighted at so wonderful a fact as a tropical shell being found near the surface in the middle of England. Nothing before had ever made me thoroughly realize, though I had read various scientific books, that science consists in grouping facts so that general laws or conclusions may be drawn from them."

Darwin's appointment to H. M. S. *Beagle*, in 1831, when he was 22 years of age, was the beginning of his serious education. (Huxley, p. 271): "While at sea, he diligently collected, studied, and made copious notes upon the surface fauna. But with no previous training in dissection, hardly any power of drawing, and next to no knowledge of comparative anatomy, his occupation with work of this kind—notwithstanding all his zeal and industry—resulted for the most part in a vast accumulation of useless manuscript." It was in geology that his training first began to show fruit. He had with him the first volume of Lyell's "Principles of Geology," and this book seems to have had a greater influence upon his scientific methods than any other one factor.

In this book Lyell expounds by the inductive method the "uniformitarian" conception of geological history, which, unlike the cataclysmic theory which was then generally accepted, viewed the course of this history as controlled by the prolonged action of the very same forces that we can study at work to-day. The influence of this volume upon him was profound and manifold; so great indeed, that later when he had convinced himself of the doctrine of natural selection, it became his conscious ambition to present his theory to the public in a book modelled along the same logical lines as Lyell's great work. Under the guidance of this book he became a keen and systematic geological explorer, and he was able at the end of his voyage to present the world with three important monographs in that science, covering the coral islands, the volcanic

islands and the South American continental regions which he visited. It is interesting that he recommends geology to his cousin, W. D. Fox, telling him that in it "there is so much larger a field for thought than in the other branches of natural history;" also "Geology is a capital science to begin, as it requires nothing but a little reading, thinking and hammering." Evidently the instinct for generalization had at last got control over him.

From this date on, investigative science becomes more and more frankly his predominant interest, so that a year later (1836) he confesses about certain ports which he expected to visit "these will be a poor field for natural history, and without it I have lately discovered that the pleasure of seeing new places is as nothing."

When he returned to England in 1836, at the age of 27, his characteristics as a scientific man were fully formed. Thereafter the chief scientific events of his life are summed up in the development and publication of the great generalizations for which he will ever be remembered. So we can stop tracing his biography, and concern ourselves with his outstanding traits.

One of the traits which shows most vividly to the reader of Darwin's letters, and of his "Journal of the Voyage of the *Beagle*," is his keen ability to place his finger precisely upon the unsolved mysteries of contemporary science, and his apparently instinctive sense as to which of these mysteries ought to be capable of solution. It is obvious what a depth of intuition he showed, when he started, in 1837, a notebook on the nature and mutability of species and varieties in nature and under domestication. The related mystery of geographical distribution is most vividly handled in the "Voyage of the *Beagle*." As early as 1835 the discussion of an epidemic among the Maories gave him the occasion for a similarly clear expression of the scientific mystery of contagion. Thus his mind was perpetually setting him problems of the most fundamental nature, which he simply could not leave alone. His son quotes the characteristic remark which a new experimental idea would often bring from him: "I can't rest now, till I have tried it."

The problems to which he gave his time were always ones which were capable of approach by the methods of a naturalist, and the naturalist's methods were always his preference. Almost always he collected great masses of facts, the qualitative range of which usually occupied his attention much more than their quantitative mathematical analysis. His method did, however, lead him to gather facts in such quantities that it was only possible to master and present them by using the simpler form of statistical treatment, and he may almost be said to have introduced this method as a mental tool for naturalists.

As to the solutions to his problems, he confesses that only in the rarest instances did he have an inkling of the right clue, until after extensive data had been collected. He mentions only one important exception to this rule, and that is one of his earliest contributions to science, the theory of the formation of coral reefs. In all other important cases he started either without any hypothesis at all, or else with a tentative hypothesis that had later to be discarded.

It is small wonder that the unwritten history of his discarded hypotheses left him increasingly mistrustful of all elaborately deductive reasoning. For all deduction is based on the preliminary acceptance of a group of laws or hypotheses. In this respect he seems to us of to-day to contrast sharply with many of the characteristics of his own age, which was certainly much given to far-flung systems of speculative reasoning.

It is possible that some one may feel like challenging this statement that Darwin's speculations were not built into far-flung and elaborate systems like those of his leading contemporaries. But I believe that his methods in seeking a scientific solution of the problem of species fully justify the assertion. When he became dissatisfied with the orthodox doctrine of special creation, he did not turn at once to one of the doctrines of descent, several of which had already been propounded. Instead he insisted upon waiting to detect some process by which species are actually undergoing transformation at the present day and then he merely pointed out that within the vast extent of geological time there was room for this process to achieve results of the most startling magnitude.

Only in the one instance of his "Provisional Hypothesis of Pangenesis" he appears superficially to deviate from his preference to keep away from elaborate systems of theory. But he was himself most keenly alive to a difference in status between this provisional, unproved hypothesis which he brings forward as probably a helpful stimulus to the investigation of heredity, and the other theses he has defended, such as natural and sexual selection, which are to him scientific principles, the actual proofs of which are already substantially in hand. Had he taken the latter attitude toward Pangenesis, he would have been committing the typical intellectual sin of his era, and perhaps of many another era, of building great speculative structures upon slight foundations.

In the second place, in spite of certain intricacies in the details of the hypothesis, the speculative foundation of Pangenesis is not really intricate. It rests simply on two suppositions: (1) that all heredity is by continuity of substance, and (2) the now discarded supposition that every part in a many-celled animal begets the corresponding part in the offspring. It follows from these

two suppositions, that the gonad or the germ plasm would not be the seat of heredity, but merely its vehicle, receiving the fundamental active material agencies of heredity (the "gemmules") from every cell of the parental body, and packing them into the germ cell. Beyond this, all that Darwin has to say about the hypothetical gemmules is that if such is the basis of heredity, then various ascertained facts regarding the course of heredity indicate that the said gemmules must be assembled, and must become active or latent according to a certain set of rules. And that, in brief, is the whole of the "provisional hypothesis of Pangenesis."

Another aspect of Darwin's scientific temperament is his absolute candor and open-mindedness. We may note a delicious instance of this, which struck his own sense of humor. In 1856 Lyell and a great many of the world's best field naturalists were accounting for the distribution of plants and animals to the oceanic islands by the theory of continental extensions to include these islands. Darwin saw strong reasons to disbelieve this, at least as applied to mid-oceanic islands, and so was in friendly controversy on the subject for some time. But if he should win this controversy, think what difficulties he was preparing for his soon-to-be-published doctrine that structural relationship meant blood relationship between the insular and continental floras! So he spent endless pains in incubating the mud from ducks' feet, to learn what seeds birds might carry on their feet, and proving such pertinent facts as that grass seed, eaten by minnows, which in turn were eaten by storks, would be avoided by the storks in a fertile condition. Referring to one of these prospective tests, he exclaims, "This is an experiment after my own heart, with the chances 1,000 to 1 against its success!" And commenting at another time upon his whole dilemma of distribution he says, "There never was such a predicament as mine: here you continental extensionists would remove enormous difficulties opposed to me, and yet I cannot honestly admit the doctrine, and must therefore say so," and then adds, "Nothing is so vexatious to me, as so constantly finding myself drawing different conclusions from better judges than myself, from the same facts."

In his self-analysis, which forms a part of his brief autobiography, he remarks that he believes himself freer than the average man from the danger of reasoning by catch-phrases. Very characteristically he suggests that his lack of facility in expression may have helped guard him against such a fault.

Another virtue which we may just mention in passing is that for Darwin every sound scientific explanation must pin solidly to earth. The mysticism of such a naturalist as Agassiz was utterly

foreign to him, so that he could only remark that it was strange so brilliant a man should express such opinions.

Many things connected with his methods of work throw an interestsing light on his character. He declares himself that during his scientific career his industry has been nearly as great as it could have been in the observation and collection of facts. To compensate for the delays caused by ill health, he kept his work methodical to a very high degree. Because of the nature of his work, he gathered great quantities of material from other naturalists, observations which they had made with other considerations in mind. It is indicative of the scale on which he gathered data, that at the height of his work he had some 40 large portfolios of classified and indexed notes. His racks of notes may be seen in the picture of his study at Down (Life I, p. 101).

Whenever he broke loose from the routine of his schedule, he called it "idling;" for example, if the work in hand was geology, and he suspended it for a few days to carry out and experiment on one of his problems.

His instinct for an inherently sound and convincing presentation of the evidence seems to have endowed him with almost limitless patience. From the date when he first began organizing his thought on the problem of the Origin of Species, to the date of the first preliminary account of his conclusions, was a period of 21 years. When the book itself appeared, one year later still, its more than 400 close-printed pages were an abstract, at about one fourth size, of the intended work, which itself was but an abstract of his argument as he had massed it in his folios. This slowness came from thoroughness, scientific caution, and mistrust of his ability to persuade, probably far more than from the more superficial cause of ill health. Darwin speaks of the advantage that he often gained thereby, in being able to criticize old chapters objectively before ever submitting them to publication.

In his correspondence, and, it is stated, in his conversation, he showed much felicity of expression. But when he wrote in argument his style was undoubtedly liable to be clumsy.

"There seems," he says, "to be a sort of fatality in my mind, leading me to put at first my proposition in a wrong or awkward form." He conquered this difficulty to some degree by "scribbling in a vile hand whole pages as quickly as possible" and revising only at a later date.

Among his personal characteristics kindliness, modesty and frank appreciation of others are most conspicuous. His modesty has often been remarked upon, but to really appreciate how deliciously far it goes, one has to read his letters at first hand.

His freedom from the trammels of tradition and his keen sympathy for every form of misfortune probably account for his description of himself as a radically inclined liberal. His anti-slavery sentiments at all times, and particularly during the American Civil War, were very intense. A most odd expression of his humanitarian interest was his attitude toward Christian missions. He was most appreciative of the wonders that had been accomplished in Polynesia, but could not believe that peoples so low in the scale as the Fuegians and the Australian Blacks could possibly receive any benefit from mission work. He expressed this opinion freely, and when finally the reverse was proved in the case of the mission to Tierra del Fuego, he enthusiastically acknowledged his mistake, and expressed it in the form of a regular annual remittance of £5 to the cause of the mission.

He had a habit of writing his appreciations to the authors of books he had enjoyed, which we can understand if we consider how greatly he himself appreciated such letters written to him. He was also a man who very quickly treated men of a younger generation as his equals, or even his superiors in science, so that he was often a great inspiration to younger men.

In esthetics Darwin had a tremendous, and it might be said, a highly trained feeling for the beauties of nature. His deepest responses were to those scenes that expressed to his knowing eye some aspect of the wonderful cosmic drama.

The wastes of Patagonia and the sight of a naked savage in his native environment are two scenes which he speaks of as most strangely impressive, evidently through the story they tell him of *das ewige Werden*. He never forgot the sublimity of the Cordillera or the lavish luxuriance of the Brazilian forests. And we have his children's word to testify to the peculiar keenness of his appreciation of the precious, homely loveliness of his own England, which seemed hardly diminished, as nearly as any of them could tell, to the very end of his life.

In music, painting and literature, he had an essentially naïve and untrained, but for the most part fairly lively enjoyment. In his later years he lost his taste for the set, formal types of literature, so that verse, or the standard drama (like Shakespeare) no longer interested him. This seems to be the principal excuse, along with the quieter enthusiasms of old age, for his self-criticism as having atrophied on his esthetic side. Yet his family reports that even totally ignorant as he was of the slightest vestige of the principles of music, he always loved to listen, and his choice was uniformly for a good quality of music. So before taking too seriously his account of his esthetic atrophy, we really ought to view him a

little through the eyes of his children and friends, and then decide how much to discount his statements on the score of his peculiar modesty.

We are especially interested to-day in the contribution of Darwin to the spirit of science, and for that reason should like to consider his spirit as it were apart from the actual intellectual content of his additions to human knowledge. That is the more possible, as we can easily imagine that even without his aid the evolutionary hypothesis might have triumphed within a few decades of when it did actually triumph. The world had become accustomed to the idea of nature acting in strict accordance with law; to the concepts of stellar evolution, and of an inconceivably prolonged geological and paleontological history. It had even been recognized that such laws as the conservation of energy and the conservation of matter were valid in the kingdom of life. Goethe, Erasmus Darwin and Lamarck had long previously directed attention to the conception of an orderly derivation of the more complex types of life out of their less complex predecessors.

To be sure, no definite evolutionary theory had as yet won any great following among naturalists, because all of them up to that time had been either too vague or else too mystical to carry conviction. Lamarck's theory, which was most prominent because it had been the most fully elaborated, had a very strong mystical element. It was, broadly, to the effect that the offspring derived their physical constitutions not merely from the physical constitutions with which their parents had started life, but also from the additional development which the parents acquired through exercise and habit, and from a vast accumulation of "prenatal influences," if I may so express it, derived from the emotional life, and more especially from the desires, strivings and aspirations of the parents during their whole life previous to the act of generation.

Other defenders of evolution through descent usually either appealed to the same group of supposed influences, or emphasized one or another factor within this group (habit and exercise, for example), or appealed to an innate or divinely instilled tendency toward structural elaboration and self-perfection.

Immediately previous to Darwin's first public announcement of his natural selection theory, things were happening that indicated the readiness of a group of younger scientists to turn attention once more to an evolutionary conception. Herbert Spencer had already indicated his adherence to a modified form of the Lamarckian theory. Huxley, who had spurned the prenatal influences of Lamarck, was in private expressing at least an equal

degree of dissatisfaction with the orthodox theory of species as independently created entities. Von Baer, in Germany, was definitely of the opinion that some form of evolution through descent would have to be accepted. Finally came Wallace's paper, independently propounding the theory of natural selection, which as is so well known was read at a meeting of the Linnean Society jointly with a brief preliminary paper by Darwin, in the summer of 1858.

Suppose now that the great series of publications by Darwin had not come from his hands, in what ways would the world of science be poorer to-day? We can easily imagine that Wallace might have won Huxley, and have found Spencer a powerful ally. Huxley was not the type of man who could have rested till he had converted other scientists, and we can hardly doubt that this gifted debater, possibly aided by others of the young biological group, might gradually have compelled the scientific world to pay attention to the evolutionary hypothesis.

Without going into detail, the same situation held true of Germany, von Baer in particular being more than ready for any rational doctrine of descent.

If through these channels a great success had by any chance been achieved, the immediately following history would have been but little different from what it actually was. For in a sense Darwin was hardly at all an active participant in the dramatic contest that waged about his book. The giants of this battle were masters of debate, of repartee, of innuendo, such as Huxley and Wilberforce, and not at all the quiet, uncontentious, semi-invalid naturalist, who in his family circle applauded alike the brilliant thrusts and neat maneuvers of both groups of contestants. Darwin's supreme ambition had nothing whatever to do with the dust that was stirred up by his book; for it was simply to be able to thoroughly convert Huxley, the zoologist, Hooker, the botanist, and Lyell, the geologist. If many other scientists were also converted, that would seem to him a surfeit of success; and as for that group which obviously could never accept his argument, he was simply astonished that they took notice and reacted so quickly and so vigorously.

The fact, then, that the "Origin of Species" became at once the bone of contention between the great schools of thought did not give its writer any great immediate power to influence the spirit of the mid-nineteenth century, which became, in spite of him, and even by reason of his contribution, more and more exuberantly speculative. The mass of his contemporaries were akin less to him than to the temperament of Herbert Spencer, of

Haeckel, and of Weismann, with their elaborate theoretical systems.

During these exciting times, the man who had started it all was quietly at work upon a book descriptive of "The various contrivances by which orchids are fertilized by insects." Incidental bits of this study came out in 1860, 1861, and 1862, and the finished work in 1862. Such was Darwin's continual attitude toward controversy—not contemptuous but simply unworried, content to make use of whatever criticism was helpful, and to watch to improve the wording in the next edition wherever it appeared that his language was honestly misunderstood.

Only a very few of the adverse criticisms touched him where it hurt. One, for example, let it be understood that he wrote with an air of cock-sureness, a sin of which he could not bear even the shadow of suspicion. At another time Darwin bursts into righteous indignation on Huxley's behalf, when he catches a reviewer ascribing to Huxley a motive in his belief—Lyell's " 'object' to make man old, and Huxley's 'object' to degrade him. The wretched writer has not a glimpse of what the discovery of scientific truth means." Such was his spontaneous outburst at the least hint that scientific opinions might be motivated.

Darwinism was the signal for an overwhelming readjustment of popular metaphysics, as everybody knows, but it really seems hard to realize to-day how deeply men's minds were shaken, all through the thirty or forty years of the readjustment, by questions of purely abstract philosophy, or to what an extent the biological scientists have taken part in the philosophic questions. To make vivid the acuteness of that old situation, we may recall how Huxley, intensely loyal as he always was to the scientific concept of causation, nevertheless declared in substance (Romanes Lecture) that ethics was inexplicable, to the best of his understanding, from the standpoint of biological evolution; or again to the attitude of Wallace (Darwinism, Ch. XV) that the higher intellectual, esthetic and moral gifts of man are gratuities bestowed upon him by a benevolent deity through agencies entirely outside of the workings of biological evolution.

In all these abstruser corollaries of evolution Darwin took absolutely no part whatever, and even when questioned he did little more than plead ignorance and incompetence. Theism seemed to him a deduction flung too far afield to be dependable. He can not help doubting whether our brain equipment was ever designed for such uses. Nevertheless, he seems to have retained to the end of his days the simple rudiment of faith that "this universe is not the result of blind chance" ("Descent of Man," last pages;

"Life" I, 286), even though our intellects may not have the caliber to prove what else it is.

In all this, and especially in his freedom from intensity over such matters, he was hardly a type of his own era, and I can not help feeling that he is more at one with the complexion of thinking men of to-day—men to whom the evolutionary conception is as natural as it was to Darwin himself, so that they are no longer fussed by its possible metaphysical implications. Like him they still possess a philosophy of life, but one that is more proximate and less abstruse than what their nineteenth century predecessors were mostly wrestling with.

Is it not possible that the older generation of teachers to-day, the men who were brought up on Darwin as their daily bread, but who on account of the mental stresses of their era had to fight to attain and to defend the true Darwinian spirit of scientific candor —that these teachers to-day are finding in their pupils youths for whom a part of this victory has been won in advance, so that scientific candor, the spirit of unmotivated judgments, is for them an easier lesson than it was during the era of storm and stress in which the teachers had to learn it?

If this description is accurate, a substantial part of the credit must be ascribed to the slow-working leaven of the personality of Darwin himself, perpetuated in his writings and ramifying through the examples of those whose scientific ideals he has inspired.

THE MENTALITY AND THE COSMOLOGY OF CLAUDIUS GALEN

By JONATHAN WRIGHT, M.D.

THOSE who think of Galen at all, even those who have had some acquaintance with his writings, think of him as a physician, but a man can not be entirely a physician without being somewhat of a philosopher.[1] Hippocrates puts it a little differently and says no one can be so well a philosopher as he who seeks the truth in a study of medicine. I am not sure there is not much that one should ponder in this opinion. Such wisdom as one arrives at in regard to the moral and physical destiny of man as well as in regard to his environment is to be garnered most abundantly close to physiological and psychological fields. Now, singular to say, the things that are most lacking in the philosophy of Galen are the ethical values of humanity in their broader aspects. Man's narrower personal outlook constantly receives incidental mention as one goes through the vast sea of his professional writings. These are commonplaces of worldly wisdom, which he did not practice very successfully in some respects, owing to his glaring temperamental defects. Into all this I do not intend here to enter at all except to repeat that his philosophy in no way entitled him to boast the proud apothegm of Terence, *Nihil humanum mihi alienum est.* In so far as man himself is part of the cosmos in its intellectual and moral spheres, Galen's cosmical philosophy is negligible.

It is however with the ultimate structure of the universe that Galen's chief interests lie in cosmical philosophy. He is the heir and one of the chief sources of our historical knowledge of the strivings of the earliest Greek philosophers after a fundamental knowledge of natural phenomena. He was educated in a thorough régime of moral philosophy as taught by the various schools of his day; but, though he shows some traces of the teachings of the Stoics, it is the physical nature and structure of man alone he studies from the viewpoint of the Nature Philosophers. Doubtless in the shaping of the humoral doctrines for their final permanency in medicine, moral philosophy has little place, but the neglect of intellectual interests in certain directions perhaps had something

[1] *Galeni de optima secta ad Thrasybulum*, Liber I, 107. In these references I use the Kühn Latin translation, the Roman characters denoting the volume of that edition and the Arabic the page number.

to do with the oppressive narrowness and the absurdities into which he guided medical doctrines and where they remained for more than 1,500 years. Despite his formal piety he was a contentious upholder of positivism—a very mule's head in debate is the only contemporary notice we have of him. His admiration for Plato was but lip service so far as the practical workings of his mind are concerned. It is true he acknowledges that though our extended acquaintance with natural phenomena is acquired through the senses there is an innate knowledge, but how it works or to what it owes its existence is not so clear. A man knows when a line is straight and when it is crooked. "Of course with asses no one permits oneself to argue, for they have no minds, so also with men who have only minds in which they have no confidence."[2] There is no use of referring the uncertainty of knowledge to one who has no organ of knowledge, he viciously says, or does not believe he has.

To tell the skeptic he is not sure he thinks because he has nothing to think with may be witty enough, if one is in the mood for wit, but it is a flippant way to discuss problems of serious philosophical import. At best it is only one of the jokes of the ages revamped in every generation. In Plato the wit in the discussion plays no less around the subject, but it is less offensive and more subtile, more suggestive and instructive. The doctrine of Protagoras that man is the measure of all things is discussed more pleasantly, more profoundly, and the argument, unflinchingly nevertheless, faces the doctrine of eternal verities in the realm of ideas. Although I have elsewhere dwelt in dissent on the inclination to place the quality of Galen's mind in the category of that of Hippocrates or to rank it with that of Plato or of Aristotle, I allude to it again, for in studying his cosmic philosophy it becomes apparent that his contribution to it contains nothing original and his comments lack originality not alone because he lived in an age long since degenerated from that of the giants of Greek thought, but the quality of his mind was a handicap which even a favorable environment could not overcome. In a way his own gibe could be turned against himself. He did not have a suitable organ to do that kind of thinking with.

It would be an endless task to select from all his writings and summarize the incidental references marking his thought as to the nature and extent of the divisions of matter, but we have one treatise[3] in the form of a commentary on the ideas of Hippocrates as to its constitution which we can use as a guide to his cosmic philosophy in the sense I have defined it. He there takes up the

[2] *Galeni de optima doctrina*, Liber I, 40.

[3] *De elementis ex Hippocrate*, Liber I, 413.

cudgels in defence of the author of the "Nature of Man," in the Hippocratic Corpus. If we were to discuss here the philosophy of Hippocrates instead of that of Galen we should have to consider the question in some detail as to this book being the product of the mind of the man who wrote the best of the books of that collection. Galen from his own limitations saw no reason why it can not be placed among them. But modern critics with Littré at their head insist this can not be done even if we consider only the tenor of thought of the writer. While some of the doctrine in it seems evolved out of passages in the "Ancient Medicine," in the latter the author advances no such vulnerable argumentation on cosmic subjects as that Galen is at pains to defend. The manner in which he does this, rather than his adoption of the opinions there found, gives us an insight into his methods of thought. It can not be said that he always defers to the opinion of Hippocrates, perhaps, though I have never been reminded he was actually contradicting him, but it is quite apparent that he does violence to the text occasionally as well as to the meaning in reading some of his own convictions or rather his own preferences into the criticisms he reports Hippocrates makes of the opinions of others.

It is curious the disciple in his commentary should deduce from the master the argument for a plurality of elements which he stresses. Man would be devoid of feeling or sensibility, and his five senses would not function, if one only element was the material out of which man is compounded. They both fail to take into account the forces working on matter, a contribution made by Empedocles, though Galen was aware of them as he mentions them incidentally elsewhere, indeed makes much of innate dynamic influences in physiological action, drawn more or less directly from that ancient philosopher. The diversity of these in their potentiality for making contrasts, whereby things are perceived by the apposition of their contraries, apparently does not occur to him. It would seem that while the argument he emphasizes is prominent in the medical treatise he ascribes to Hippocrates, "The Nature of Man," it might be allowed to pass as the superficial argument of a writer who had specialized on medicine and was not concerned with ultimate cosmic doctrine. Whether it is a genuine treatise of the great Hippocrates or not, it is not one to which great weight can be attached. In the books now considered genuine, Hippocrates so far as I know makes no use of this argument. It follows from the terms of the doctrine of Democritus that his atoms, the ultimate divisions of matter, are devoid of qualities in themselves but give rise to the perception of sense only by means of the kind of impact they make on the animal structure. By the way in which Plato treats the doctrine of Protagoras, really based on some such view

as this, we see this taking into account of the dynamics of matter is fully exhibited, though presumably Plato is hostile to Democritus, for he never mentions him. Galen and the author of "The Nature of Man" take in this connection no account of it at all. We get at least a hint of it in "Ancient Medicine" which has more claim to being genuine. Indeed if Galen had commented on the elements of Hippocrates in this book he could not well have escaped the consideration of that point.

Aristotle had declared that essentially the doctrine of Empedocles was one of duality—that for him in reality there were two elements, force and matter. Galen does not pursue the discussion thus far; he only says if there were but one element no sense perception could arise. He thinks the impact of two atoms of the same substance in space could give rise to no quality. Indeed he seems to reject the whole atomic theory because of this apparent inefficiency in originating objective phenomena, since in its terms as familiar to him, "no atom is penetrable or capable of sensation."[4] At any rate this difficulty in the atomic theory for him seems to have been one of the things preventing him from accepting monism in cosmogony. He does not develop here the ground on which his objection to it rests, but the inference is plain we only recognize the definition and limitation of matter, indeed the existence of matter at all, by the existence of its attributes or qualities, and these we apprehend through the existence of opposites. A thing is bitter because we know what is sweet, a thing is hot because we know what is cold. This was commonplace among philosophers, and Galen evidently did not consider it necessary to enlarge upon it. Manifestly, if there was only one element, an indivisible portion of matter, opposites could not exist in it and hence knowledge through the senses of matter in general could not arise. We need not stop to discuss this point of view. We can see by reference to the gibe I have quoted he must have thought the contribution of Protagoras to philosophy negligible. If the senses tell us nothing as to realities, he may have thought, they are at least all we have to rest on in cosmology. Most of the philosophers, Plato preeminently, refused to accept this, and we have now long bid farewell to the senses, before Einstein, as the limit of ascertainable knowledge. I cannot see that he reaches this level in philosophy at all. He remains at that of Herbert Spencer, who declared we must start with the knowable. This is all right for any one who knows what the knowable is, but it does not form a very solid basis for those, who, in Galen's words, possess only minds in which they have no confidence. Galen was a positivist, but I confess I am often at a loss in some of the phrases he uses involving this point,

[4] *Ibid.*, p. 421.

though we get a hint as to the origin of some of the narrow bias of his thought in this defence of the "Nature of Man." His pursuit of humoral doctrines in the practice of medicine led him astray. Not only, he says, would man be devoid of sensibility if there were only one element, but incapable of generation too, that being, we may suppose, also an apposition of contraries. Then, if there were only one element, there would be only one disease and one treatment.[5] One may well doubt if the real Hippocrates or Plato or Aristotle ever reasoned with such loose ends as these, but obviously the turn of the argument is again a Spencerian one. In modern phraseology we would say a monistic homogeneity, a real monism, precludes the possibility that out of it heterogeneity can arise. I am not capable of passing judgment on this. I am only trying to trace out his thought in modern terms, and I am forced, in order thus to follow it logically in a modern view, to make some inferences which may be erroneous.

If he apparently falls short of the ancient viewpoint in this respect, and his repetitions serve to remind us of his embarrassment, in quoting them in their varying phraseology we get a suspicion he did not go the limits reached by Democritus and the older philosophers as to the possibilities of the ultimate division of matter. "If any one pricks the skin with the finest of needles, the animal suffers; the point touches only one or two or perhaps many atoms. First suppose only one is touched. No atom can be pierced and it is not susceptible of sense,"[6] etc. His mind almost sticks at the conception of the size of the point of the smallest needle and does not in any event arise to the contemplation of the minuteness of the division of matter nor of its energy demanded even by the ancient theory. Yet so common at Athens, 500 years before, was the conception of the vortex of atoms and their other mobilities that Aristophanes made fun of it on the stage. He finds difficulty, too, in imagining how out of senseless and impenetrable atoms sentiment and easily penetrable flesh can be formed at all. The vastness of the world of being lying between the ultimate atom and the proximate finger pulp his mind could not grasp, "for who will not wonder that flesh when pricked suffers, when its finest particles can not be pierced or made to suffer?"[7] I may be pardoned for lingering thus over the difficulties of a mind in many directions wonderfully acute though lacking that essential of all great minds, imagination, as exhibited in an author so influential as Galen in shaping the future thought of the world. It can not be denied that his mentality was in type that which is often referred to in modern parlance, perhaps not so much now as when positivism

[5] *Ibid.*, p. 436.

[6] *Ibid.*, p. 420.

[7] *Ibid.*, p. 423.

was at flood tide, as the only one for a man of science. I imagine we are to trace to an actual degeneration in the coordinating habit of the human intellect the sinking beneath the horizon of a conception of the cosmos as structurally beyond that furnished by the senses. It has had to be resurrected in our time before further advance could be made in a real knowledge of the fundamental facts of physical science. It was a conception familiar to Empedocles. I am not prepared to say if this submergence, after the great Greeks, is an anatomical, a dynamic or a social phenomenon of degeneration. It seems reasonable to think rather of the latter.

Monism, if not the whole atomic theory, being in Galen's view a doctrine incompatible with observed facts, he approaches a plurality of the elements with more caution than we might expect: "How many there are altogether is as yet undetermined. Therefore we will inquire into the matter." He finds other theoretical reasons, it is true, than the necessity for the supply of a sufficiently large enough variety of combinations, but as is well known he not only accepted the tetralogy of the elements, which Empedocles and his predecessors had presumably derived from Africa[8] but he forced a host of phenomena, by means of the humoral doctrine, into the same narrow numerical confines. We will have to admit that in the then state of knowledge, the acceptation of earth, fire, water, air as elements was the most useful formula possible, however erroneous, for attacking the huge problems of physical science lying ahead of the human mind. Even from these some think "if they are sufficiently multiplied, varied, altered, transmuted, something may arise, which may be of another kind than that already existing."[9] Aristotle, as has been noted, imputed the thought to Empedocles and at least all the modern systematist needs is two, that is, matter and energy, but it is obvious that the former without the latter is unworkable, however successful the modern monist may be in getting along only with the latter. Failing to take note of the thought, evident at least in Aristotle, that energy may be regarded as an element in apposition to matter, really amounting to a dualism, we easily perceive Galen's inability to accept a monism. We have difficulties of our own. The modern human mind falters also, though, astounding as it seems, there are indications of modern man's belief in the possibility of breaking away from the human mind in cosmic theories, and this possibility Empedocles also seems to have played with, but such transcendentalism was not for Galen. However, I am plumbing the shallows of my own mind and ought not to speak for that of my congeners.

[8] THE SCIENTIFIC MONTHLY, April, 1921.

[9] *Galeni de Elementis ex Hippocrate*, Liber I, p. 428.

Galen reminds us of what seemed to him a quite obvious fact. The monist, whether ancient or modern, is, by virtue of his belief in a single element, a mutationist, a believer at least in the multiform aspects of a matter forced on our attention. That all the most ancient philosophers must have been, not only Heraclitus, who so strikingly phrased the idea, namely, that we never step twice in the same river, but Thales and all the rest. Manifestly earth, water, air and fire turning into one another has always been the only way for the monists to keep their doctrine in court. It is all one primordial substance, from which each is severally evolved, and when the argument takes a mystic turn this primordial substance may be unknown to us by our senses, or, out of one primordial element, water, for instance, the others are being continually evolved. The idea of Melissus[10] that the whole universe is compounded of one immutable form of matter is too ridiculous. Aristotle as well as Hippocrates rejects this. It is not necessary to enter into the subtleties of the argument of Parmenides, but it is well to remember that if Plato did not stand in awe of him he respected him highly and portrays Socrates, despite his mock humility and sardonic humor, treating him with more real respect than he exhibits toward most antagonists. Parmenides defended this thesis in the abstract, and doubtless this was one of the reasons why by some historians he is said to have reduced the Eleatic philosophy to absurdities. At any rate Galen is in good company in refusing to accept the ideas of Melissus as worthy of discussion, but when he attempts to give some explanation for the origin of the qualities, he stumbles and falters even in his attack on Athenæus Attalensis,[11] who defended the idea that the qualities were elements, an idea on all fours with the frequent lapse we seem to note in ancient arguments when they treat abstract conceptions as material realities. Moisture in the highest degree as an attribute of matter is water; the hottest heat the ancient knew was fire. In fact, the latter exists before fire, and from it fire is generated when great heat is introduced into fuel.

Under the terms of the argument as they appear in the account of Galen we might think it was a drawn battle, for when dryness and moisture were harnessed up with the other two (earth and air) elements, something else might be deduced. Dryness it would be hard to make into earth, however complete, and coldness could hardly have turned into air. There the facile illustration might have been balked, it would seem to a modern, but that was not the trend of Galen's refutation. We can refuse to believe either was right, but neither is that the point of interest for us. Under what

[10] *Ibid.*, p. 447.
[11] *Ibid.*, p. 457.

aspects could such doctrine be presented by either side to the controversy with such force as to satisfy any ancient mind that it was an explanation of cosmic philosophy? One of Galen's home thrusts is that cold disappears when heated and the dry when moistened. To us this seems proof sufficient that there is no such thing as the cold or the dry, just as Protagoras had pointed out by non-experimental methods, but this was not for Galen. I doubt if any one generation can ever throw light into all the blind alleys of the workings of the human mind in a former age. In some long gone past, when the doctrine of opposites was a fruitful theory we may conjecture some philosopher, seeking to extend its field of usefulness, pressed the opposites of cold and dry into service and they remained fixed in men's minds for thousands of years. We see Galen close to the path that the hot and the cold are but man's evolved reactions to degrees and kinds of molecular motion. It is true we have no reason to marvel that he did not see it all, but that he should not have stepped out of the path of error and into the path of truth after the early Greeks had shown that man arbitrarily makes himself the measure of the qualities of all things, creates them indeed, is reason for reflection on the imbecility of the human mind. That a part of the difficulty is the fault of the inadequacy of language to express human thought, of which it is called the vehicle, is quite probable. There are all sorts of nouns according to the rules of grammar, some substantive, some abstract, some generic, etc. Ancient thought tended to confuse not only the quality, the adjective, with them, but as moisture was the watery, so white tended to become whiteness and moisture at times became as substantive as water. How much this was a confusion of thought and how much it was a verbal confusion, it is not always easy to discern. There is a book,[12] evidently spurious, attributed to Galen in which we come in full view of these difficulties where according to the title the discourse is about what qualities are corporeal, but we meet with the awkwardness which becomes an actual aberration of thought even in this book on the elements of Hippocrates and in the genuine treatise against Lycus.[13]

For the most part, however, Galen was aware and critical of this pitfall of ancient thought, though he seems occasionally to fall into it himself, for Galen's idea at times seems to be that heat and humidity can differ just as color or pleasure do. The fire may be made from wood or from straw and thus it differs. This throws the modern mind into panic and confusion, and we can not forbear seeing a source of error in such divagations. In his strug-

[12] *Galeno adscriptus liber quod qualitates incorporeal sint*, Liber XIX, p. 463.

[13] *Galeni adversus Lycum libellus*, Liber XVIII A, p. 196.

gle with Athenæus we see the hot becoming pure heat, which is fire, and we then wonder ourselves a little whether qualities are corporeal or not, so bewildered do we become with the phraseology. Is there, then, such a thing as hot heat? That is what Galen seems, when we have become quite helpless, to be driving at in his discourse with Lycus. By means of our appreciation of a hot fire we conjecture he is speaking really of the degrees of heat (the strength of its own activity, Galen puts it), and again we find his feet unawares in the right path. Then a thing is whiter, he says, because it has in it more of whiteness. Thus he hands on to the puerility of the Middle Ages the sophisms of antiquity. Thus he drifts into the common error in primitive thought, much heightened doubtless by the contention of Plato that after all ideas are the only realities; but back of it all we see the mind of primitive man utterly unable to differentiate the material from the spiritual. That was the heritage Plato had from an intellectual heredity already remote in his time. We see the trace of it with especial distinctness in this spurious book on the corporeality of the qualities, deeply tinged with theological infusions.

In résumé we may say, then, that Galen, with the good backing of Hippocrates and Aristotle, denied monistic doctrines and their corollary of mutability. This in reality was probably necessary for the advance of knowledge since the complexity of the problem, as we now know it, was simplified by the false stand taken, but his great predecessors did not anywhere in their genuine works state it as uncompromisingly as did Galen. "It may be boldly asserted earth, fire, air and water are the primary and common elements of all things, since these constitute those bodies which are included in the totality of things first of all and the most elementary to that degree that all other things, vegetable, I insist, as well as animal, are made from these."[14] Whether sensation is present in some one or other of them or results from a combination of them he is not so sure. The perception of the qualities depends on this, he seems to think, and though there are numerous others, those of the hot and cold and moist and dry are the fundamental qualities from which the others arise. All this Galen must have absorbed from his environment and from his great predecessors among the ancient Greeks. He scarcely made a single addition to their philosophy or contributed an argument that had not been used before. Yet his dogmatism, for good or for evil, crystallized the hitherto fluid thought of the older nature philosophers, so that it stood the neglect of a thousand years, and thereafter the assault of new ideas for almost half as long.

[14] *Galeni de elementis ex Hippocrate*, Liber I, p. 456.

THE READING OF CHARACTER FROM EXTERNAL SIGNS

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THE relations between general psychology and individual psychology are important and not hard to grasp. Neither can be separated from the other in practice, but each has its set of problems and its complement of special methods. The problems of general psychology concern the determination of laws and principles applying to the human animal generally, which are either independent of individual peculiarities or inclusive of these idiosyncrasies as definite combinations of general factors, not as exceptions. The problems of individual psychology, on the other hand, concern the discovery of those factors of difference between individuals; thus, ultimately, the description of the important respects in which each individual varies from other individuals, and in as far as classification is useful, the assigning of each individual to the class or classes in which he belongs. The specific methods of general psychology are included under the general term *experiment*; the methods of individual psychology under the term *mental measurement*. The most obvious relation between the two branches is through the fact that reliable mental measures (commonly called *mental tests*) can be developed only through experimentation of the most rigorous kind, and the fact that general principles can be obtained only by taking into account the individual differences of the various reactors on whom experimental work is done. One of the most unfortunate and harmful details of the present enthusiastic movement in the individual psychology, in education, in industry, and in medicine, is the naïve assumption that persons ignorant of general psychology and untrained in experimental psychology can develop and apply mental tests in a useful way without the careful supervision of competent psychologists. The deleterious results of such bungling work on children, for example, are apparent not only in the harm to the children and needless trouble and expense to which parents are put, but also in the prejudices aroused in the public mind against mental measurements as a result of the mistakes of amateurs. Equally unfortunate results are frequent in the legal, medical and indus-

trial applications of amateur psychology. The general recognition of the need of individual psychology in commerce and industry in particular has led to the existence of a class of mere exploiters, many of whom reap large financial rewards from their practices, and whose eventual effect on the manufacturers and business men they victimize is to turn them against the application of real psychology.

Mental measurements have so far been developed to the point where effective determinations of general intelligence are made—determinations which are of value not only for schools and colleges, but also for commerce and industry. No psychologist claims that these measurements are completely satisfactory, and we all know that they are being constantly improved, and will be enormously improved in the future. On the other hand, no one but the psychologist knows the amount of time, labor and personal training required for the development and standardization of even the simplest test. The public, impressed by the apparent simplicity of the materials, assumes that any one can make up a test, and the public is right so far: any one *can* make up a test, and almost every one *does*, but the tests are not worth anything. The public either does not see this, or, if it does see it, assumes that the tests made up by the expert are also worthless. For some of the confusion the psychologists themselves are partly responsible. For example, the nomenclature of "mental ages" as established by intelligence tests, which should never have been allowed to escape from the laboratories, has very much confused and prejudiced the public.

In addition to tests of "general intelligence" (which may most safely be defined as that which standard intelligence tests measure), tests for special intellectual capacities have been developed. We can now measure ability to sustain and to distribute the attention, ability to perceive accurately details of various kinds, ability to learn, ability to avoid learning, and many other special abilities of this class. The field of such measurements is rapidly being extended, and it now requires merely the application of the labor of the trained psychologist to develop systematic tests for the special combinations of intellectual abilities required in any branch of any trade or profession.

But this is the limit to which mental measurements so far have extended. Emotional and moral characteristics are not as yet measurable. Yet we know that these characteristics are of immense importance in all the divisions of life in which we are measuring intellectual capacity. Even as concerns the candidate for admission to college, while it is important to determine his

intellectual capacity, emotional and moral factors ought to be known. There is many a man who goes down or barely survives in college, whose intellectual ability is sufficiently good, but who will not work, or who will get into trouble because of moral delinquency, or whose scale of values is inadequate.

I do not say that we shall never be able to measure these characteristics by the methods of individual psychology; in fact, I think that ultimately we shall compass such measurement. A number of us are now at work on the problem of moral measurements, and I think the prospects for development along this line are favorable. But at present we do not pretend to make standardized measurements of emotional and moral capacity.

Wherever there is a great need, attempts to fill it will be made; these attempts will not all be scientific, and not all made in good faith, especially if there is a prospect of fat remuneration. The historical development of medicine is an illustration of this fact. Medical practice developed long before there was any known basis for it, and the bane of the medical profession to-day is the tendency to apply something in cases where there is really nothing to apply—a tendency against which Osler and other medical leaders have protested emphatically, and with some success.

The past lack of scientific means of measuring intelligence, and the lack of scientific means of measuring moral and emotional characteristics, together with the real need for such measures, has led to the development of unscientific methods of mental diagnosis which are popularly designated as *character analysis*. These methods are based on the assumption that there is a close relation between the anatomy of the individual and his mental characteristics, and that the details of this relationship may be discovered by casual examination, without the aid of statistical methods or experimental procedure, by persons ignorant not only of psychology but even of the rudiments of physiology.

The first systematic attempt at the development of character analysis was made by the phrenologists. The physiologist Gall early in the nineteenth century began to teach that the mental life is largely dependent upon the brain, especially upon the cerebral hemispheres. This fact was not widely recognized before the time of Gall, although it has become a commonplace since then, and Gall's work had a large influence in bringing this recognition about. But Gall and his disciples are also responsible for the introduction into psychology of several misleading conceptions concerning the relation of the brain to consciousness—conceptions which have re-

tarded the development of psychology and which are being eliminated but slowly. Gall and his pupil Spurzheim developed a theory of the relation of the brain to mind which they called phrenology, which means literally the study of the intellect. These phrenologists believed that the different faculties or capacities of the mind were localized, each in specific portions of the cortex or outer surface of the cerebral hemispheres. They further believed that the relative development of each of these faculties depended upon the relative size of the portions of the brain in which the respective faculties were supposed to reside. Highly developed philoprogenitiveness, or love of children, for example, was supposed to depend upon a cortex relatively thicker in the philoprogenitive area than is the cortex in the same area of a person less strongly philoprogenitive. Finally, since they supposed the conformation of the skull to agree with the relative thickness of the cortex it encloses, they assumed the possibility of diagnosing the development of various cortical areas by examination of the outer surface of the cranium. The surface of the head was accordingly mapped off into a number of small areas, each associated with one of the faculties in the phrenological list; and from the relative depression or elevation of these areas the phrenologist attempted to read the "character" of the subject.

We need not dwell upon the series of bold assumptions involved in this system, since, from the scientific point of view, the system is of historical interest only. Quite aside from the further development of phrenology as a technique, it had a profound and on the whole unfortunate influence upon the course of psychobiology for many years. Physiologists and psychologists fell into the habit of assuming that consciousness is dependent upon brain activity in a remarkably simple way, ignoring the complicated interrelations of the various parts of the nervous system, and ignoring the fundamental function of the total nervous system in the control of movements through sensory stimulation. Moreover, both the psychologists and the physiologists accepted even the phrenological doctrine of the localization of conscious functions in specific parts of the cortex, although the functions as thus localized by the physiologists were not the "faculties" of the phrenologists, but a more generalized group, including the senses. It is only within the last fifteen years that psychologists have begun to reject the phrenological theory, and many physiologists still cling to it.

As an art, phrenology had a wide popular vogue and is still practiced lucratively in the United States, there being at least one school in which the system is taught. It has, however, sunk to a position of relatively minor importance, and has been largely

supplanted by newer systems, in part derived from it, and in part derived from still older anatomical beliefs. In these newer systems little emphasis is placed upon the surface of the skull, the major stress being laid upon the contours of the face, upon the size and form of the nose, mouth, ears, brows and eyes, upon the color and texture of the hair, and upon similar anatomical traits.

In one of the most widely known systems, from which many other systems have been drawn, "conscientiousness" is indicated by a broad, bony chin; "benevolence" by a full, rolling, moist under lip; "love of home" by fullness of the soft part of chin just below the lip; "amativeness" by the thickness, moisture and redness of the central part of the upper lip; "cautiousness" by an extremely long nose; "judgment" by a broad, large nose; "observation" by a lowering of the brows at their inner ends and projection of the frontal bone at that point. Musical talent is indicated in this system by an ear of rounding form and fine quality, with a deep bell and perfectly formed rim. Mathematical ability is shown by squareness of the face bones, width between the eyes, and especially by the upward curve of the outer part of the eyebrow. The signs of acquisitiveness are a thick, heavy upper eyelid, with fullness and breadth of the nose just above the nostril. Sometimes an arched, curved or hooked nose indicates the same thing. But in this system the significance of many signs is modified by others; hence, the degree of development of a given characteristic is read, not from a single anatomical sign but from a group of anatomical details, to which I will apply the term *physiognomic pattern*. Thus, a certain relative form or size of one feature might indicate a certain mental trait, provided it is accompanied by certain other details of form, position and size of other features. Linguistic ability, for example, is shown by large bright convex eyes, fullness under the eyes, the rounding out of head above temples, full lips, full cheeks, full throat, wide mouth and chest, large nostrils, length from point of nose to tip of chin, with vertical, lateral and perpendicular width of concha of ear. The physiognomic pattern indicative of well-developed color sense is decided color of the complexion, eyes, eyebrows and hair, clearness of skin, and veins showing through.

By the use of patterns instead of single signs there is secured an elasticity of application of the system, which is of great importance, and to which I shall later refer.

The foregoing samples are drawn from a single system; but this system is one from which a number of variant systems have apparently been derived. There are many systems in use, all equally definite, all equally "successful." Some systems stick

pretty closely to physiognomy; some add signs from the voice, posture, and the anatomical details of arms, leg and trunk. But all these systems agree in two points: They are in the main anatomical, and they are lucrative to their promoters.

The attempts to read character from anatomical signs have not, however, originated in modern times, nor have they been confined to professional character analysts. Evidences of popular associations between anatomical details and especially between facial and mental and moral traits are to be found in the literature of all peoples. "Let me have men about me that are fat," Shakespeare makes Cæsar say. Confluent eyebrows have long been supposed to be evidence of a lecherous disposition; a long nose of meddlesomeness; red hair of passion; and so on *ad infinitum*. As an attempt made in all seriousness to evolve a scientific system of mento-anatomy, I may point to Lombroso's description of the criminal type. It is evident that we have here to deal with tendencies which are widespread, and which are by no means always operating in the interests of private profit. Yet it is the professional character analyst who forms the main problem, since it is his work which furnishes the most pernicious results.

It requires little investigation to convince us that the systems of character analysis now in use have no scientific foundation, and that if any one of them were in part valid, it would be a most marvelous coincidence. None of the authors of the various modern systems shows any evidence of knowledge of physiology or psychology, to say nothing of genetics; nor do they attempt to apply even the simplest principles of statistics or experimental procedure in arriving at their conclusions. Naïve conclusions from selected cases at the best, mere guesses at the worst, are the sole means employed. A study of works on physiognomy strongly reminds the reader of the interpretations of the psychical researchers and the Freudians. Aside from this, the contradiction of system by system would give even the layman cause to doubt. If we consider the signs of the same character trait, such as "honesty," we find it indicated in different systems by quite different signs. If we consider the same sign, such as the shape of the nose, we find it indicating quite different traits in different systems. And yet the claims of any one system to practical success are as well substantiated as are those of any other system.

Nevertheless, the incompetence of the existing systems does not dispose of the question whether there might not be a valid system evolved. In spite of the futile efforts of various would-be flyers, the airplane was invented. We must inquire therefore what possible basis there is for a system of character analysis based on ana-

tomical signs. And we find the answer that there is no known basis on which such a system might be constructed.

We know that the exercise of mental and moral capacities does not change the gross anatomical details of the human being. (Some of the systems of character analysis assume the contrary.) That a man can not, by taking thought, add to his height is true, and is an illustration of a more general law. No exercise of generosity, judgment, musical talent, malice or amativeness can change the form of the nose, or of the ear, or the setting of the eyes, or the form of the brows. If training can not develop anatomical signs, then the putative signs of character must be signs of inherited capacity only, showing the endowment of the individual in respect to capacities which he may or may not have cultivated and developed.

But the results of genetics to date give us no basis for assuming anatomical signs of inherited capacity, except in pure races or relatively homogeneous races. It is true that we may conclude from such signs as the shape of the eyes and the color and texture of the hair that a certain individual belongs to the Chinese race, and hence that he has traits of character common to the Chinese. But the Chinese race, although not an absolutely pure race, is one which is sharply distinct from the white races, and we may expect to find different racial characteristics, although as a matter of fact the characteristics usually imputed to the Chinese are probably due more to training than to heredity. A Chinese boy, brought up under white conditions, is surprisingly like a white boy mentally, although he retains his anatomical race characteristics. In the case of the negro and of other markedly inferior races definite racial mental differences may be admitted. But we must remember that these differences are racial, not individual.

The European races, however, are exceedingly mixed, being the products of the blendings of many stocks, and although it is possible that the original pure stocks may have had specific anatomical characteristics and also specific mental characteristics, we find no linkage of these characteristics in their hereditary transmission after mixture. A remote ancestor of a certain man may have belonged to a stock which had long noses and also had violent dispositions; another remote ancestor may have belonged to another stock, having snub noses and great amiability. The man under consideration may, however, have inherited the long nose from the one stock and the amiable disposition from the other. This fact comes out most clearly in the blendings of the white and negro races. The features of the mulatto or the octoroon give no indication of the relative mental inheritance of the individual from his white and colored progenitors, although statistically the greater

the proportion of white ancestry, the greater may be the probability of white intelligence.

It is possible, although not probable, that our feeble-minded whites inherit their mental defect from certain original pure stocks of low mentality which unfortunately became mixed with the other European stocks, but there are no anatomical signs by which the feeble-minded may be identified. Nor are there any anatomical signs of the criminal, Lombroso to the contrary notwithstanding.

It is true that there are certain exceptions to the generalizations I have made. Cretins, microcephalic and macrocephalic individuals and other distinctly pathological cases show anatomical signs of their mental deficiencies. So does a blind man show that he is deficient in the visual faculty and the legless man show his deficiency in the faculty of locomotion. But these cases are due to specific defects, and have no bearing on the attempts to analyze and classify the common run of humanity. These pathological cases may be easily segregated, and character analysis contributes nothing to our identification of them. In the remaining bulk of the population there is no discernible principle of linkage of the mental and the anatomical.

Finding no scientific basis for the anatomical character analysis, we are now thrown back upon the pragmatic problem. How is it that these systems apparently succeed? And we must admit that they do have at least financial success, for many of the character analysts are making money from their practice on commercial and industrial concerns.

For this success there are two outstanding reasons: first, the actual value of character readings is rarely checked up; second, a few, not many, of the professional analysts, when subjected to actual tests, can make surprisingly good guesses.

As an illustration of the way in which character reading may obtain the prestige of success without being checked up in regard to its accuracy, I may cite the case of a large industrial plant, in which several thousand employees were "analyzed" by a reputed "expert" at a good round price. This expert had a system devised by himself after the usual type, and apparently drawn either directly or indirectly from the older system from which my illustrations were taken and from which many other popular systems are drawn. This self-styled expert told me that in his opinion the systems of several other and better known fakers, whom he named, were defective because they were too rigid. "Now I," he went on to say, "have used in my system all that is worth while in psychology, phrenology and physiology; but I am not hide-bound like the others. When I find a case to which the system doesn't apply,

I discard the system and use common sense." This expert spent several minutes in interviewing each employee, marking on a form card the characteristics of eyes, mouth, ears, hair, head form, etc. Then, combining these records, he decided upon the general mental and moral characteristics of the individual, and upon the particular line of work, if any, in the plant at which he should be put.

The "experting" of these employees was done at the instance of one of the directors of the corporation who had become interested in this sort of "efficiency" through the "success" obtained by it in certain other corporations. By the time the analyses were completed, this director had lost interest in this particular fad, and had become interested in another kind of "efficiency." The results were, of course, pigeonholed; the managers and foremen who were actually working with the employees knew too much to use the readings. But the "expert" went on to the next job with thousands of dollars in his pocket, and with the reputation of having successfully "experted" this corporation, whose directors, being cold, hard business men, obviously would not have put money in the scheme unless it were financially profitable. This corporation, of course, had been influenced by similar considerations. Other concerns had their employees "experted" "successfully," the success having been of the same imaginary sort.

"Success" under the conditions of an actual check up is another matter, and it is said that certain "experts" have, under test conditions, achieved a surprising measure of success. Such tests are made by submitting to the inspection of the "expert" a number of individuals of known and proven capacity in various lines, but who are unknown to the "expert." The "expert" is then required to make a written statement as to the mental characteristics of each person, and these statements are compared with previously prepared statements based on the established characteristics of the test-persons.

Now I can not guarantee that any such tests have actually been successful. I have to restrict my statement to the form "it is said." There are, of course, many chances of erroneous conclusions when the tests are not made under the rigid supervision of psychologists. We know from the alleged proofs of telepathy and of various forms of spirit manifestations that unskilled investigators commonly overlook the most vital points in the test conditions, because they do not know their importance. The records on most tests of this sort have a value of approximately zero, because they contain no reliable evidence on the vital points, however much detailed information is given on other points.

But suppose we assume (although we may have as yet no good grounds for the assumption) that tests of certain character-analysts have given positive results. This would not be surprising. In fact, I should expect to find that some "experts" could produce positive results. Few "experts" are willing to submit to real tests, but those few who are willing must be so because they are confident that they could succeed to some extent, even in a carefully checked test.

We may freely admit that certain persons, working in entire independence of any system, may be able to make some good guesses. Many of us think that we can make good guesses. Our guesses are probably very much less accurate than we suppose, yet they may have some validity. In many cases we have to entrust important matters to individuals as to whose honesty or intelligence we have no evidence except from our guesses based on brief observation of the visible appearance of the individual. There is no reason to suppose that professional character analysts should not be able to make as good guesses as any one else, provided these experts have the requisite native capacity, and provided that, like the one I quoted, they ignore their systems and use common sense.

It is actually a fact that we do make correct judgments about the transient mental processes of other persons without being able to identify the facts on which these judgments are based. If you are talking to some one, and you say something which offends or grieves or pleases him, you may recognize that fact at once, although it may be impossible for you to designate the exact change in his face or voice or posture which is the basis of your idea. You may even make similar judgments when carrying on a conversation over the telephone, in which case changes in the timbre and inflections of the voice alone could give you the clue. You know from the other person's voice that he is offended or pleased, although you may not be able to identify the exact change in his voice which is the important factor. When you have the visual clues from the other person's face, as well as the clues from his voice, your judgments are more definite and more secure.

This whole matter is but a special case of the more general phenomenon of perception and judgment by sign. It is a fact that in much of our perception we perceive meanings without perceiving the signs on which the perception is based. In some cases, the signs could be perceived, if attention were drawn to them; in other cases, the signs can not be discriminated even under the best conditions. I shall not go into this topic in an extended way, both because it is familiar to psychologists, and because it can not be briefly expounded to those without psychological training. I men-

tion it only to show that on this point of character readings we are not dealing with a unique phenomenon, but with a particular manifestation of a general principle which runs broadly through our mental life.

As another illustration of the general principle, I may refer to certain cases of supposed "thought-reading" which are really cases of sign-reading. Many amateurs succeed in catching ideas from other persons, where there is physical relation of such sort that movements of the second person may actually stimulate receptors of the first person, either tactually, visually or acoustically. But these amateurs never succeed if they watch for the signs. They succeed only when they ignore the signs and attend to the meanings. In fact, if amateurs who succeed brilliantly in muscle reading tests become convinced that their performance really is muscle reading and nothing more occult, they can usually do the trick no longer, and this is precisely what we might expect. Similarly, if, instead of watching to see whether the person you are talking to is pleased or not, you watch for the facial changes which indicate pleasure, you will not catch his emotional changes unless the symptoms are extremely gross. The conditions here are not greatly different from those obtaining in the visual perception of depth, where, if you attend to the signs, convergence, accommodation, binocular disparity, and so on, you will lose the depth-effect which those signs would give if they were not attended to.

The important question, therefore, is: What are the signs which tell us something about the mental characteristics of other persons? In the case of fleeting, ideational and emotional changes, these signs are obviously not anatomical; and in the case of fundamental tendencies of mental and moral sorts, we have already shown that there are no known anatomical signs. We are, therefore, forced to the conclusion that in the one case as in the other, the signs are physiological. Changes in the complicated muscular system of the face do occur along with ideas, especially if these ideas are emotionally toned. Changes in the complex musculature of the vocal organs and changes in the arm, leg and trunk muscles also occur. There are, in other words, changes in voice, in features, in posture and in other bodily postures and movements which are perfectly competent to serve as indexes of ideational and emotional changes. Unfortunately, we have not yet succeeded in analyzing more than the most gross of these signs.

Fundamental tendencies in ideational and emotional reaction give rise to habitual modes of expression of the various sorts. Habitual modes of expression, moreover, leave their traces, especially in the face, even when the actual expression is not occurring.

There would seem to be, therefore, a complex system of signs, not only of fleeting mental changes, but signs also of character traits, provided we can make use of them.

Signs of this sort are effective, prior to analysis. Habits of perception and of judgment are built up on signs, without necessitating any analysis or identification of such signs. Moreover, the development of the capacity to catch meanings in this way, if it be possible, depends upon native capacity as well as upon practice. We should, therefore, expect to find exactly what we do find, namely, that there is great individual variation in this apparent skill, and that in the absence of a really comprehensive and accurate analysis of signs, the attempt to attend to signs is a disturbing factor.

Character analysts, if successful under real test conditions, obviously make their guesses just as you or I do. "The systems" can be nothing but obstacles, since they have no real bearing on the problem. But, after having made a guess, the analyst can readily find in his system details which back up his guess, provided the system is elastic, depending upon sign patterns rather than upon hard and fast single signs. We need not assume that successful character analysts, if there are such, go through this sophistical process deliberately. The tendency to construe evidence to suit one's theory, and to recognize the data which may thus be construed, overlooking conflicting data, is too well known and too widespread to need demonstration. One of the important reasons why scientific procedure and scientific methods are necessary is that such procedure and methods are indispensable helps to the avoidance of arbitrary inferences, and even with the best of scientific aids the tendency will sometimes operate.

As a matter of fact, there is no reason to believe that the accuracy and reliability of such guesses as you and I and the character analyst make are very high. But there is reason to believe that if any character analyst does obtain even ten per cent. of accuracy in certain special test cases, he very likely may not know how he gets his results, and may believe that he is getting them through his system, although he really is not.

I have no doubt that those mind-readers, such as Bishop and McIvor-Tyndall, who apparently attained striking results under test conditions, sincerely believed that they were reading minds directly, and not through physical signs. Certainly, they could obtain those results only by ignoring the signs, and it may well be that they would not have been successful if they had known the actual nature of the process. I may mention here the observation I have made that the most successful hypnotists are those who have

no scientific comprehension of the hypnotic process, but who really believe that they are exercising an occult power, or that some "magnetic fluid" flows from their hands to the patient.

On the other hand, it is true that we do, in much of our perception and thought, make use of signs effectively, although we are fully aware of the nature of those signs. In visual depth perception, to which I have already referred, we lose nothing in the perception of depth in pictures and landscapes through an exact knowledge of the signs, provided we do not attempt to attend to those signs in the moment of perception. As another pertinent illustration I may point out that the knowledge that the thinking-process proceeds through muscular signs does not interfere with the vividness and the efficiency of thinking, provided we do not attempt to attend to those signs while thinking.

It is therefore entirely possible that a scientific system of character measurement may some day be developed. Such a system would be based on physiological, not on anatomical signs, and would necessarily be the result of extensive and prolonged experimental work. Even the development of such a system to the point of such relative efficiency as has been reached in mental measurements would require years of work by many and highly trained investigators, just as the development of mental measurements has required.

Although we do not know that it is possible to develop a science of character estimation, serious work in the attempt to find out is highly desirable. Even a definite negative result would be most valuable. In the meantime, a respectable name by which this field of investigation might be known would be practically useful. The term "analysis" and its derivatives can no longer be used in psychology, because, thanks to the efforts of the "psycho-analysts" and the "character-analysts," the terms "analysis" and "analyst" have come to connote superstition and quackery. In the meantime, in the interests of the gullible public as well as the interests of psychology, both pure and applied, we must carry on an educational campaign against "character analysis."

MAROONED IN A POTATO FIELD

By Professor EDITH M. PATCH
MAINE AGRICULTURAL EXPERIMENT STATION

THE circumstance of my exile was in accordance with the rule of contrasts, by which life whets her sense of humor. For it is given even to those who, following the traditions of eight generations, were born within forty miles of Boston to will to go the way of the winds when spring beckons their gypsy instincts; and I confess to taunting visions of elephants dancing in the jungles of one continent and tadpoles named Guinevere disporting in the southern pools of another—glimpses of desire that blurred my eyes a bit as I reached the end of my own so different journey and found myself marooned in a potato field.

An amazing number of the helpless little *solanum* inhabitants of the field were being drawn and quartered and buried at the time. Their graves stretched out in interminable rows, vast cemeteries of tediously straight ridges, alternating with shallow-furrowed barren valleys.

The cemeteries being filled, the surplus *solanums* were being taken to the crematories, called, in the language of the Aroostook, "starch factories." The hearses—long, low-bodies, high-wheeled vehicles locally known as "jiggers"—were laden with staved and hooped coffins, known in the vernacular as "bawr'ls," twenty or so to a jigger; and the procession of these hearses drawn up before each crematory was seldom less than thirty long.

The whole affair that first day impressed me with funereal gloom; a sentiment shared, no doubt, by many an Aroostookian except, of course, the proprietors of the crematories, who were buying for thirty-five cents a barrel the same grade of tubers that, the previous year, had found their way to a different type of market at ten dollars a barrel.

As if to ease my mood with the consolation of sweet companionship, a voice reminded me of a near presence in the familiar words, "Yes, dear, I'm here. Yip, yip, yip, yip!" I laughed—not at the owner of the voice, but at the absurdly huge joy that surged up to welcome him, for it was the first time I had ever noticed that the song of a vesper sparrow is magically sweet. Previously I had always considered the performance a miserably minor affair, but

now even the yips with which he superfluously punctuated the assurance of his proximity borrowed a musical glamor from my pleasure at being greeted—not, mind you, by an elephant dancing in a Kipling jungle nor yet by Guinevere mysteriously frolicking in a Beebe pool, but by the most commonplace sparrow of my acquaintance.

His music was symbolically prophetic, for 'twas to be the natives who were to keep my heart warmed through the dreary initial month of my rustication. Deserving of mention in this connection was little Billy Woodchuck, with whom I was soon on calling terms (though truth compels me to admit that this social function was from first to last strictly one-sided), a frequenter of Stoneheap near Hill-Lane, and 'twas there I met him first.

To say that the pleasure of this meeting was mutual would be to exaggerate, for at sight of me Billy froze into brown and gray shadows among the stones. So I nestled into a fence corner to meditate upon these cool camouflages of wild beasties turned, like a cold shoulder, against all humans, both the just and the unjust. Presently, however, the shadows again resumed the semblance of Billy and crept out on a rock and faced me and whistled. I liked his tune, the better, perhaps, because I could not interpret it.

As I rose to go at the conclusion of my call, Billy slipped to the ground and stood up on his feet like any parlor gentleman. He dropped his hands with Delsartean grace and stood erect and quiet as I departed. When I had gone on a bit along Hill-Lane, I glanced back at a picture that will cheer my memories of woodchucks—great Stoneheap in the near background and in the front little Billy standing between two big rocks with his left hand resting lightly against one of them and his right hand drooping languidly.

When next I saw him he was down in the field, creeping on all fours, with wisps of dried grass sticking out from the sides of his mouth like a fierce bristling mustache. Just why this strange behavior, only Billy, and perhaps one other, more in his confidence than I, can explain. At any rate it intrigued my interest, and when later on the superintendent remarked at Sunday supper that one of the farm hands had taken the gun and had gone out to shoot a woodchuck, my appetite suddenly weakened. The superintendent's interpretation of this murderous errand was that a chuckhole is dangerous in the mowing—a horse might step in and break his leg. But I was skeptical. Haying time was weeks away, and it was not the future and uncertain fate of horse-legs that stimulated this bit of Seventh Day sport on the part of the farm hand. Nothing so altruistic as that. He had suffered, doubtless,

an inevitable reaction from his day of rest and, not being addicted to the type of diversion that some of his associates have been alleged to smuggle across the near Canadian border, he had sought the solace of a gun. Thus, for Billy's sake, I reasoned bitterly to myself, even as that supper tasted bitter to my palate. And I was right, it seemed; for by and by the brave hunter returned with his borrowed gun and the complacent report that he had missed the woodchuck and killed a skunk. Not with the same aim, I took it, though I did not inquire for particulars. What I noted was that he was quite content. His own personal Sabbatical craving for excitement had been satisfied, and charitable interest in the problematic question of broken horse-legs was forgotten. The festive holy-day murder of any one fellow creature had served his purpose as well as that of any other.

Well, Billy was safe for the present. I had that to be thankful for; though I did regret the untimely loss of Mephitis, a large and handsome fellow I had taken considerable pleasure in watching as he scurried with rustling haste about the woodlot from one old stump to another, in frantic quest of buried treasure he seemed never to find. Yes, I mourned the loss of Mephitis, even though for certain inherent reasons I had not hoped to form so close an acquaintance with that black and white denizen of the woodlot as I had with furtive Billy Woodchuck. For I had found that this little chap, who was so delightfully surreptitious about bringing stones and earth out of his dugout and carrying hay in, would venture forth and gaze at me even when I came so near his doorway as six feet. That is, he would if I sat there long enough and quietly enough and if that black rascal of a gossiping Corbie didn't happen to be about and caw down a warning appropriated by Billy. It was remarkable how well Billy understood Corbie's signals. I saw him time and again stand up suddenly, when that busybody sounded an alarm for all the countryside to take notice that an interloper was at hand, and gaze and sniff first this way and then that, quite certain that something had gone wrong. And when he saw the intruder he would sink by imperceptible degrees into his hole, so slowly that even while I watched I could hardly see a motion; only where there had been a woodchuck, erect with drooping paws, there would be at last only a hole in the ground.

Of course in northern Maine there should be partridge cocks strutting about before their families, and antlered moose feeding in the open, and dappled fawns treading their dainty way, and little bear-cubs at frolic. But there are not. At least, in all the hours and all the miles of my three months' residence I did not see one there. For the Aroostook is not a forest, but a potato field.

An old settler, proud as of a miracle performed, stood on a height with me one day and boasted in terms of contrast, "When I first came here, there were forests as far as eye could see."

Well, it was a miracle, man-wrought, a typical agricultural triumph. And the sun of that day, when the heat went to 97 in the shade, scorched my mind with wondering why we, who for generations have been over-anxious lest we suffer after-world hells, have been so industrious in destroying the controlling factor in our water supply in this, our present heaven. During the weeks of dusty drought, when the potato buds shriveled and fell, the query was inevitable: Had we not already overdone the potato acreage a bit? Would the Pine Tree State, in the practical interests of the potato and other economic crops, not have done well to conserve a grove here and there? Not, of course, for emotional or esthetic reasons, but out of cold Yankee shrewdness! These meditations were authoritatively dispelled by the voice of an official visitor to the county—a man from the national Department of Agriculture, who indubitably knows what is good for the future of the potato business. He was saying, with an appraising gesture toward the only remaining parcels of untilled land: "Of course these marshes have some of the most fertile soil. They can be drained and brought under cultivation with even less expense than the work that was involved in getting the forests out of the way."

Farewell, Orchids and Thrushes

But it was not to bemoan the circumstance that fawns and cubs had been ousted and that thrushes were threatened nor to console myself with droop-pawed woodchucks that the treasury of the United States *via* the treasurer of the University of Maine was paying my salary. Mine was a stern commission, and if it was somewhat grimly undertaken it was because I was in personal rebellion against my professional duty.

For I feared that at the close of the season it would fall to my lot to report in the interests of agriculture, to whom I am a servant, that there is no guarantee for healthy potatoes grown within aphid flight of a rose-bush. That was a sad thing to have to face—being hangman to the rose! Surely agriculture is a cruel and exacting mistress. She has beheaded the red cedars in the vicinity of apple orchards, condemned the currant and gooseberry in the interests of white pine, banished the barberry from the neighborhood of grains, because of what fungus specialists have told her. And now, on the word of an aphid-hunter, was the rose to be outlawed from potato land?

These premonitory reflections were soon interrupted by an

event of some importance in Aroostook. The graveyards indicated in the second paragraph of this record were the scene of a resurrection. Like the children in Maeterlinck's "Blue Bird," we saw demonstrated the thesis, "There are no dead," for the long brown ridges were crested with living green. The miracle had taken place—the potatoes were up! But the coming up of potatoes is not so simple a matter in the Aroostook as elsewhere, for that is a north country and because of the frost and for other reasons, too, the crests of green are buried alive. Once and again and again the ambitious plants were subdued. Each time they showed their heads they were heaped over with earth until at last the ridges were so very high and the valleys between were so very narrow and so very deep that the horse-hoes could do no more, and then the aspiring plants were finally permitted to breathe the air that they had repeatedly struggled to reach. Perhaps no one but an Aroostookian treats potatoes so roughly, but the growers there are proud of their school of "high hilling," and a "low hiller" in that country is another term for slacker.

About the time that the plants were progressively and conclusively up, an epidemic of solanimania broke out. Everybody caught it and rushed to potato fields like mad dogs to water. Immediately the vocabulary of the place became suggestive of an insane retreat and everyone chattered in his own vernacular to the confusion of everyone else. The call of the hour, "Let us spray," was observed by all; but the baptismal creeds for potatoes proved as numerous and varied as those for people. There was no quarrel as to the necessity of bordeaux, but the manner of its application seemed still to be in an experimental stage. Arsenic in some form was advocated by all, but chemists nowadays are talking a language unknown to one who grew up in an age when Paris green was in vogue and London purple not quite forgotten. Nicotine sulphate was commonly accredited, but was it actually necessary to hit the aphids with it or did those delicate creatures succumb to the fumes if enough of the stuff was let loose among the rows? Must the underside of the leaves be covered, and, if so, were the undershot nozzles more effective than a drag boom? Was that faithful old standby, the Watson, to be superseded by a haughty new-fangled power sprayer? And was poison dust, if administered at 4 A. M. in the dew, more efficacious than a wet application?

While the spray gangs were still raving about such simple problems and some too involved to lay before an innocent public, other victims of solanimania broke out with symptoms no less pronounced. One man was cherishing about five thousand seedlings in the hope that one of them might give promise of a better potato

than the markets had heretofore welcomed. But there was no time to enjoy a bewildered appreciation of the possibilities of five thousand new potato seedlings before it became evident that the growers of old varieties had been taken with violent spasms of weeding. Now, weeding a potato field does not mean removing plants other than potatoes from the scene of action. Most of that operation comes under the caption of hoeing. When a potato grower "weeds" he digs inadvertent "cobblers" out from among his "green mountains" and removes the adventitious "bliss" or "silver dollar" from his "cobblers." For a potato field in the land where seed tubers are grown is not a mere field of potatoes but a field devoted to some one variety uncontaminated by a chance specimen of some other equally palatable variety. One soon learns in the Aroostook how to tell one potato from another potato.

Nor was the madness of the season confined to Maine. A man from Bermuda roamed about Aroostook County seeking "certified bliss." Out of Vermont came a farmerette in knickerbockers questing from Presque Isle to Prince Edward Isle for "certified green mountains."

Not guests alone but the mails bore evidence that the epidemic was widespread. From one state in the middle west came the announcement (received by a sceptical world) that a strain "immune to potato mosaic" was under successful cultivation. From the state next beyond that came the appeal: "Would you mind giving me some information on the distribution of *Empoasca mali* in your state? As you know, here in —— this insect is a very bad pest, causing *hopper-burn* and many other diseases and possibly producing a disease eventually causing the potatoes to run out." And by humorous coincidence, in the same mail as that, there arrived from Burlington, Vermont, an advance announcement beginning, "Tip burn as a physiological disease has been one of the much discussed questions at recent phytopathology meetings since our entomological colleagues have endeavored to carry it over into their camp, ascribing it to an insect and renaming it *hopper-burn*."

Not science alone became infected, but art as well, as witness: "About the first of next month I shall be in the Pennsylvania potato center. There water-color studies of spud plants are to be perpetrated."

No one, apparently, was immune. I contracted the malady and had as bad a case as any one. A characteristic symptom was a fevered emphasis of one's own particular bias. Mine was the rose-bush. For weeks, as in a delirium, I saw little other than rose-bushes. No devotee of the ancient order of whiskey ever had more vivid visions of reptiles than I of rose-bushes. Indeed, the

knickerbockered farmerette from Vermont protested that she could never again think of me without the memory of my hand waving toward the wayside vegetation while I yelled above the din of the "rattling good" government vehicle: "Beside the last potato field was a rose clump a rod long! See ahead on the right, the whole fence is bordered with roses." Thus from Presque Isle to Frenchville and return, and again from Houlton to Presque Isle.

For the fate of the rose was not alone at stake. My professional reputation as an aphid detective hung also in the balance. My colleagues, the plant pathologists, had challenged me.

It came about thus. A few years previously the plant doctors who spent their summers hobnobbing at Aroostook Farm had informed me that my pet aphid, *Macrosiphum solanifolii*, was spreading their pet potato disease from sick plants to well ones. Said disease (spelled m-o-s-a-i-c but popularly known as "mozik") is not so especially disastrous in the north in potatoes grown for the table; but the south looks to the north for seed, and a tuber with a taint of mosaic in its substance grows, after being transported to the south, to a miserable plant, indeed. Now there is this similarity between the egg business and potato growing—there is no excess profit in the product grown for the table, but for the man who can dispose of his product for purposes of propagation there is a possible fortune. The seed-potato industry, actual and potential, means a great deal to the state o' Maine. And it was threatened, they told me, largely because my "pet aphid," a million or a billion strong, was inserting its beak into the tissue of sick plants and, after imbibing mosaic juice, dispersing to other parts of the field and inoculating healthy plants with the disease.

Their question as to what I would advise under the circumstances made me feel a bit responsible for my insect charges, albeit with something of a lump in my throat, as I replied, "Remove the wild rose-bushes from the borders of fields where certified stock is desired for seed purposes."

My suggestion being met with a sceptical frown from my phytopathological colleagues, I recalled to them the story of *Macrosiphum solanifolii*:

This insect is a migratory species. During the summer it produces viviparous generations abundantly upon potato and certain other herbaceous growths that it accepts as "summer hosts." In late summer and early fall, winged individuals are developed which migrate from potato and other summer hosts to the rose-bush, where subsequently appear, as progeny of the winged migrants, wingless egg-laying females and winged males. The eggs of these apterous oviparous females are deposited on the rose-bush, and remain there unhatched until spring, this plant accordingly being termed the "overwintering host." About the time the new growth of the rose is in its tenderest and most succulent condition in the spring, the aphid egg hatches and the

young insect grows into a wingless viviparous form—the progenitor of all the succeeding generations for the season and hence called the "stem-mother." The daughters of the stem-mother grow up on the rose, part of them with wings and part without. The winged daughters fly forth to seek their pleasure (*i. e.*, a summer host, not hard to find in a land over-run with their favorite sap) and start on the potato vines, the summer colonies, which are augmented a fortnight later by the advent of their nieces from the rose—for their wingless sisters, remaining on the rose, produce winged daughters which migrate in their turn to the potato fields in the vicinity. Thus the cycle runs—the spring migrants going from rose to potato, their progeny unto several generations dwelling on the potato as a favorite summer host; fall migrants winging their way back to the rose where the fall generations, the over-wintering egg and the spring forms reside.

But this recital did not dispel the sceptical frown before alluded to. In fact there was nothing new in the story, for I had told it first as long ago as 1915. The plant doctors had, indeed, but one comment to make. When I wound up with "Obviously the destruction of the wild roses in the vicinity would break the aphid cycle," they remarked quietly, "Of course we may have overlooked them, but we have never observed many wild roses in northern Aroostook."

That was their challenge. It was admirably done, I think. A courteously constrained statement bearing directly on the point under consideration and characteristically conservative, as is the habit of one scientist (if he be discreet) speaking to another. But that brief guarded sentence was charged and I knew it questioned whether I was sure that *Macrosiphum solanifilii* overwintered on the rose, wholly on the rose, and nothing but the rose? As an aphid detective working out the life cycle of this species in Penobscot County, what did I know about the conditions in northern Aroostook where, according to resident observations, wild roses are, at least, comparatively rare?

Certainly that much of professional criticism was implied and possibly a running personal stricture may have been included. At any rate, I found myself wondering whether my colleagues were registering a disappointed conclusion that in failing them at an hour of need I was demonstrating some inherent disability leading to an inference that entomological work in general and the task at Aroostook Farm in particular was after all a man's job! There was, perhaps, a personal "dare" as well as a professional challenge in their significant suggestion that a recommendation to uproot wild roses where wild roses had not been observed to be rooted down seemed hardly in order. Obviously there was but one thing to do either on professional or personal score. The various due official sanctions having been all registered by November, 1920, the next May I laid aside the garb of a laboratory entomologist and donned the khaki of a field scout.

Naturally, first came an intensive quest for wild roses within dangerous proximity to potato acreage. For, as I had taken my "pet aphid" on rose annually since May, 1904, and in seventeen years' collecting had never found the spring generations on any other vegetation, there must be no data overlooked in this particular. How many miles afoot this quest led me, I can not state, but it was as far as one could explore in the days of a fortnight, down one side of the hedge rows and lane rows between farms, and up the other; in and out and round about the bordering woodlots; wading beside marsh fringes in rubber boots; and tramping forth and back along the length and breadth of hillside pastures. And in none of these places did I find a wild rose-bush. News of wild roses in river thickets reached us by way of botanists and fishing men; but (fortunately for one in sympathy with wild life conservation), it did not, in the localities visited, seem necessary to seek them out.

For without that we found rose-bushes, plenty of them, and that along the broad highway! There were dooryard roses near Aroostook Farm, thousands of stems of them, in both directions, within short walking distance. The wheel of the field assistant helped add to the same sort of data; and later by automobile route we saw them at Fort Fairfield, Caribou, Van Buren, Frenchville and all along the roadways between them and Presque Isle. Surely the life-cycle of *Macrosiphum solanifolii* is in no danger of breaking in northern Aroostook for lack of rose sap. That became evident to us all before the summer was over. But incidently there were some very puzzling questions presented by these northern dooryard roses.

Of course it was no surprise to find *some* cultivated roses at and beyond Presque Isle. The plant doctors in attendance on sick potatoes had indicated their presence in the quite logical statement that it hardly seemed probable that cultivated roses would be abundant enough in that locality to keep the aphid supply going. It hardly did! For even at Bangor we are north of the "real rose" zone. We have even here to fall back largely on *Rosa rugosa*, though especially ambitious care provides for cherished ramblers and a limited number of other varieties. But the outstandingly queer thing about the roses of northern Aroostook is that the most vigorous clumps of them are not cherished at all. They grow in neglected masses which give no evidence of pruning shears for two decades at least. And often as not the grandmother of the house would say, "Oh, those are nothing but *wild roses*. Our garden roses," indicating feebler growth, "are here."

That was a riddle unguessed for weeks. Why, when failing in

such places as wild roses are wont to grow wild in, judging from an acquaintance with their ways in other parts of Maine and in other states, should they be so abundantly common in dooryards, especially in old dooryards or spots marked by fire signs or crumbling cellar walls, where once dooryards had been? Your consulting nurseryman can tell you readily enough, but at that time it was a conundrum to me.

But making sure that there were rose-bushes enough to hold all the overwintering eggs of *Macrosiphum solanifolii* necessary for a thoroughgoing aphid plague was not ascertaining that this insect did not also secrete those wee glistening black oval objects on other vegetation as well. And, casting aside the prejudice born of seventeen springs' collections I sought stem-mothers and budding spring-migrants on every kind of plant—tree, shrub, and herb—that I met in a three weeks' tramping. The bicycler, to whom thanks should be rendered, extended the bounds of this quest, as he did others and being without prejudice of previous acquaintance with the tricks and the manners of the insect in question, he may have been the better scout.

However that may be, no tree or herb yielded us spring colonies of our potato aphid, and neither did any shrub except alone the rose, though our search was compounded of diligence and patience.

Nor did the same vegetation yield so largely of other species as might have been expected. Fewer than a century of aphid-species represented our total season's catch. Now fourscore different species of aphids out of a possible four hundred, and not large colonies at that, comprise a meagre showing, leading to the conclusion that 1921 was a poor year for aphids in that locality. A logical explanation of their scarcity was not far to seek. For neat-winged "ladybird" beetles (five species of them) were feeding only less greedily than their brood of scrawny young; gold-eyed "lace-wings," dainty in every respect except as to their brand of perfume, were leaving their stalked eggs where their sickle-jawed progeny might merit the name of "aphid-lion;" several species of bandy-bodied syrphid flies were providing for the continuation of their kind in the same way; a fungus disease was throwing its fatal spores broadcast; and insect-eating birds were as much on duty as could be expected, considering the number of murderous cats wickedly permitted to threaten agricultural prosperity. Now with ladybird beetle, aphid-lion, syrphid maggot, fungus and insectivorous bird (in so far as vouchsafed) in combination against them in a single season, could aphids be expected to wax fat and multiply?

However, nearly two decades of official service in the capacity

of aphid detective leads one to take such seasons with philosophical fortitude. Besides, even the lean years often give significant data and it may not be without interest to mention one "by-product" of the quest of 1921, namely, the accidental discovery that two of our migratory currant aphids spend their summer season imbibing the sap of "willow-herb," a by no mean unwelcome addition to the aphid lore of Maine.

Returning to *Macrosiphum solanifolii,* it may be stated that by this time the scouting done at Presque Isle and farther north brought forth no data conflicting with the tenets that the rose is the only plant in Maine normally serving as over-wintering host for this potato aphid; that in general aphids are conspicuously more abundant in potato fields near rose-bushes; that certain fields in northern Maine, where potato mosaic, though present, was not appreciably increasing, were coincident with an annual scarcity of aphids; and that the logical conclusion was that these same "certain fields" and similar locations might be made well-nigh immune to potato mosaic if the sick plants were to be culled out ("rouged" is the technical rendering of this practice) and the area cleared of such rose-bushes as are not considered precious enough to be served with an annual anti-aphid spray of fumigation.

Does this conclusion thrill the reader (as it does the writer) with an envying realization that a partnership in the business which might be carried on in said "certain fields" would be an amazingly inviting venture? If not, it is because you did not hear what price "per bawr'l" the man from Bermuda was offering for "certified bliss," nor meet the man from Florida who had a fortune to exchange for "certified cobblers."

With the situation thus indicated for Maine, what could be more desired by way of education through compared conditions than a visit to New Brunswick? For New Brunswick and Maine are rivals in the seed-potato market: New Brunswick has cherished a hope that she has some natural advantages peculiar to her location, and Maine has been a bit afraid that might be so. It was, then, with a quickening professional pulse that I accepted an invitation to join, as consulting entomologist, a party of plant pathologists, representing the governments of the United States and New Brunswick, who were touring that province.

We visited during the trip more than eighty potato fields sufficiently to observe and record the significant phytopathological and entomological facts with reference to the potato-mosaic problem. Except for a few generalities, I will spare you all but three locations.

Because there is yet no automobile trail direct from northern

Maine to the Chaleur Bay district, we rode from Perth to Fredericton along the St. John River—a scenic day that makes one glad that there are woods growing in places too wild of contour to be shackled even by stern Mistress Agriculture. Thence our way turned northerly, beyond first one and then another Miramichi River until we reached the "Bay of Heat" where our chief interests centered. On Shippigan Island we visited five potato fields. The aphid count for the three further fields registered zero. That for two twin-sized fields, separated by a tiny meadow, within stone's throw of the ferry landing, was recorded as "a few *Macrosiphum solanifolii.*" The reader is by this time sufficiently initiated into the mysteries of the hunt to see why it was logical at this point for the consulting entomologist to hazard the statement, "There are rose-bushes nearer the ferry-side fields than the other three." But because there were no rose-bushes in sight, the reader may be permitted also to enjoy briefly the flippant phytopathological query as to whether the aphids may not have arrived *via* the ferry line?

However this was really no laughing matter. If *Macrosiphum solanifolii* overwinters only on rose, roses must be there even if they are invisible! I confess to a feeling of panic as I continued what looked to be, on account of the time limit imposed, a vain search. Then, when, in the middle of the shorn meadow separating the two potato fields, I came upon the stubs of a lilac clump, hope revived. For lilacs are not native to Shippigan Island. Where a clump of lilacs make shift to grow, there was once a dwelling, even though the ruins that marked its site are gone. It was as if those lilacs beckoned, and on hands and knees I followed the clue as diligently as any other Sherlock Holmes, and found at last, among the mown grass stubbles, the stubbles, too, of mown rose-stems, short but thrifty. Here then was bait enough to tempt the fall migrants from the adjoining fields—the link that kept the cycle of the potato aphid intact on Shippigan Island. And the thorns that pricked my hands as I plucked an evidential stem from the ground caused a pain that was physical merely and healed completely by the salve of a triumphant spirit.

The next morning a peninsula, a small almost-island, near Shippigan was visited. In the two fields first entered, aphids were disporting themselves somewhat freely. They were less numerous in the third field, fewer still in the fourth, and in the midst of the fifth field I gathered my courage and said, "We are going away from the source of infestation. The rose-bushes are nearer the first fields. If we had time we could find them." To which our guide replied quietly, "We will take time."

The inhabited dooryards in the vicinity were innocent of roses,

but behind the two most heavily infested fields we found a cellar ruin, along the walls of which the prophesied rose-bushes were growing. And also, in this deserted dooryard, long since forsaken, a great mass of the same sort of roses grew clumped over an area as big as that covered by the ruins themselves. That was a neat demonstration of a scientific method, was it not? To tell by looking at a potato field whether one was approaching or receding from a rose-bush. I hoped the phytopathologists did not guess how glorious a moment that was to the consulting entomologist. For the hero of Conan Doyle's pages never felt more keenly a triumph in tracing to a logical conclusion a treasured hypothesis.

But the silly pride that surged up gratefully to greet those roses soon ebbed. There was that about them that touched more deeply. Their true romance was after all not of the brain but of the heart—hearts long since dead. And over the graves of their memories the blossoms of roses smiled that day. For though the sun of August shone upon them, and the reddened rose fruits spoke of a full spring-time blow, a few belated blooms were now in flower. And the frail sweet things echoed as with the music of forsaken gardens.

Those roses, blossoming *in memoriam* over the graves of forgotten homes of yester-long-ago, lure my desire across the sea to the land mayhap where Evangeline's kin once dwelt. Perchance such roses grow even yet in old world places—not dooryards belike, but in untilled tangles; I think so—wild roses, their single blossoms rich of hue, and their leaves a hard clear yellowish green, fresh and clean even under August suns. And if it seem unlikely that the old-world folk brought so common a thing as a wild rose with them, may it not be that their choice double darlings were grafted on a sturdier stock? And after the bitter cold winds of the "Bay of Heat" had blasted the tender growth, the neglected root-stems came unto their own blossoms even in the stern wilds of their adopted land! How otherwise?

Later that same day we saw again that rose of yester-year. This was near "Black Rock." Our guide called a halt there and pointing to the left said, "There and a bit beyond are two fields which registered last year a score of one hundred per cent. mosaic."

One hundred per cent. mosaic! My pet aphids must have been busy. Somehow the fact that there were no roses in sight had ceased to trouble me. I left my comrades clicking their counters in the potato fields and struck out alone along a bordering lane. It led me back beyond the potatoes, beyond a mowing and beyond an oatfield. There I found them—my rose-bushes, a great and ancient mass of them, pushing against a fence that headed a high

bank. When I had returned and made my report, the others of the party went to view the roses with, it seemed to me, a certain curiosity. Indeed, when they caught sight of the great clump, the guide, regarding me somewhat quizzically, demanded, "Do you mind telling me how you *found* these roses, coming directly to them?" And I replied, with a laugh, "Scotch second sight." Who knows? There are times when something seems to click in one's brain as if some charged current from without is turned on, and the resulting action hardly seems one's own volition. And it is a common enough feeling, with reference to any "inspiration," that it "comes to one."

But I am no dabbler in psychic concerns—that way dangers lie for scientific methods. There was, of course, no mystery about finding hidden roses. It needs no diviner with a witch-hazel switch. Doubtless I found the stubs of mown roses on Shippigan Island because I had learned from experience that roses are likely to be planted by the same hands that cherish lilacs; those of the neighboring peninsula from the pure mathematical deduction based on the relative numbers of aphids in the different fields; and those of Black Rock—well, how else than by sheer accident?

At any rate, we saw no more roses like those of Shippigan during the rest of the trip, after we left the old French settlements and visited places settled long ago by the Irish. Not that here were, for all that, a dearth of roses, but they were of a different sort—"wild Irish roses" we dubbed them, though I have a suspicion, based on their habit of growth, general appearance and one dried and crumpled blossom, that they may be what we call in New England "old-fashioned cinnamon roses."

As you see, there was this in common in the single "old-garden roses" of Chaleur Bay, the "wild Irish roses" and the single "wild roses" neighboring potato fields of northern Maine—they grew in or near oldtime dooryards in large massed clumps betokening many years of age.

Surely the rose has nestled too close to the heart of man not to strike with its thorns the hand that is raised against it. Although on entomological evidence it could be sentenced to banishment by authority of crop-pest commissioners, government officials of neither the United States nor New Brunswick would probably care to undertake the unpopular task of exterminating a plant so rooted in human sentiment.

And yet, in the immediate vicinity of northern seed-potato fields, the rose will go. How otherwise? For the man from Bermuda will still come seeking "certified bliss," and the gold of southern states will demand healthy tubers. The northern growers will volun-

tarily attend to a matter that bears so directly on their purses. They have troubles enough without those borne by the wings of migratory aphids.

These were a part of the composite reflections of ninety days that conversed with me as I took a solitary walk across Aroostook Farm the night before I left. The skies were rich with sunset radiance and the glory of rainbow. Under their beauty spread out for interminable miles the potato fields in which I had been marooned for three months by the calendar. As I looked across as much of the green-leaved sea as my gaze could cover, a shiver of revulsion swept over me—a feeling more nearly akin to weary hate than I would think possible to have for any growing plant. There was something hideously manufactured about the landscape, artificially colored with prescribed baptismal dopes; and I detested the whole sprawling amorphous brood of *Solanum tuberosum.*

Was I then at last cured of my attack of solanimania? Had I shaken off the delirious taint of the potato kingdom? Ah, no, no one ever recovers. And a day or so later, when sitting before my long deserted desk at Orono, I drew into place a blank sheet of paper and headed it:

Maine Agricultural Experiment Station
Bulletin No. 303
"Rose-bushes in Relation to Potato Culture"

And the things written under that caption brand the writer as a faithful servant of agriculture or, if you prefer, a servile slave of the spud.

THE REINDEER HERDS OF THE PRIBILOF ISLANDS

By G. DALLAS HANNA
THE CALIFORNIA ACADEMY OF SCIENCES

THE domesticated reindeer of Siberia were first introduced into Alaska in 1892 through the efforts of the missionary, Rev. Sheldon Jackson. The total number brought across Bering Sea was but few more than a thousand when the Russian Government prohibited further exportation. This nucleus has grown enormously and has been divided into a large number of separate herds. The success of the enterprise is apparently assured for many generations and the native race of Eskimos was probably saved from extermination through this single stroke of philanthropy. The people not only derive food and clothing from the herds, but the meat has been sold in ports as distant as Seattle and San Francisco. Nothing but a brilliant future can be foreseen for the industry at this time.

Most of the Alaska herds have been divided and subdivided to such an extent, and the records are so scattered through govern-

Photograph by Dr. L. H. French

FIG. 1. SIBERIAN REINDEER HERD NEAR NUSHAGAK BAY, ALASKA.

ment reports, that it is difficult to secure data on rates of increase. This, however, is a matter of no little interest in science as well as in industry. It so happens that there are two independent herds on the Pribilof, or Fur Seal Islands, which furnish records of considerable value in this respect.

Through the efforts of Dr. Barton Warren Evermann, when chief of the Alaska Fisheries Service, herds were started on St. Paul and St. George Islands in 1911. The beginning was made with 25 and 15 deer, respectively, and each year a census has been made. The animals practically run wild so that a count of the sexes separately has proved impracticable, but the total numbers are very trustworthy. The counts as published each year in the reports of the Alaska Fisheries are shown in the following table:

CENSUS RECORDS OF PRIBILOF ISLANDS REINDEER HERDS

Year	St Paul Island	St George Island
1911	25	15
1912	40	25
1913	52	36
1914	75	58
1915	92	62
1916	111	85
1917	144	96
1918	155	114
1919	164	123
1920	192	125
1921	250	160

It is shown in the above table that the original herd of 25 deer on St. Paul Island has increased to 250. In addition to these an even hundred have been killed for food. On the smaller island of St. George the original herd of 15 has increased to 160 and 89 have been killed for food. The records of killings date from 1915 and are as follows.

REINDEER KILLED FOR FOOD ON THE PRIBILOF ISLANDS

Year	St. Paul Island	St. George
1915	3	
1916	6	3
1917	9	6
1918	12	8
1919	14	22
1920	22	31
1921	34	19
Total	100	89

Thus the total strength of the two herds in 1921 was 350 for St. Paul Island and 249 for St. George Island. When we consider that the animals have had no care whatsoever that reindeer need,

Photograph by Dr. L. H. French

FIG. 2 FEMALE AND YOUNG OF SIBERIAN REINDEER NEAR NUSHAGAK BAY, ALASKA

the condition would seem to be very satisfactory and Dr. Evermann deserves great commendation for having overcome the many obstacles in the way when the introduction was made in 1911. Persons familiar with the raising of these animals in Norway state that in 10 years the original herds of 25 and 15 should have increased to 500 and 300 respectively, if they had received proper care and attention and if the surplus males had been regularly removed. A much larger number could also have been taken for food. Nevertheless, the records possess a peculiar interest because the herds have been allowed to revert to the wild state.

The average increase each year has been a little more than 33 1/3 per cent. when the animals killed are added to those living. It is a little less than that figure when only those living are considered.

The full significance of this may be better understood if comparison be made with other animals which bring forth but one young each year, such as the fur seals, for which the Pribilof Islands are famous. In the same ten years the herd of these animals has increased at an average rate of only about eight per cent. per year. The difference in the rate is not due to the longer breeding period of the reindeer, but to the enormous destruction of the fur seals in the sea by killer whales. At least fifty per cent. of the young born each year fail to reappear the third year following, and the work can be laid only to the killer, because the actual amount of pelagic sealing by man is small.

As stated above, the reindeer have reverted to the wild state. The business of the inhabitants is the taking of seal and fox skins and they give little attention to the deer. The animals are never herded or placed in corrals. They resort to the distant parts of the islands where they seldom see human beings and have become almost as wary as wild caribou. No use is made of them at all except for food.

Some of the surplus males are now taken each winter and the herds show considerable improvement since the practice was started in 1915, as a careful examination of the above tables will demonstrate. Before that time the fighting of the males was a detriment to the herd in several ways. They not only killed or injured each other, but they injured some of the females as well.

The killing is done with high powered rifles, not a commendable practice, but the only practicable method when the animals are allowed to become so wild. The shooting not only makes them

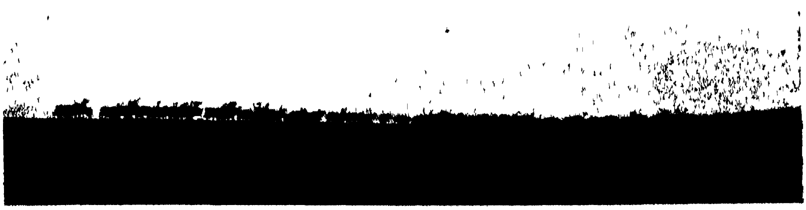


FIG. 3 ST PAUL ISLAND REINDEER HERD IN 1919

wilder, but results in the occasional killing of a first class female by mistake. In one case one male and two females were killed with one shot fired into the herd.

As to the already great value of the herds to the U. S. Bureau of Fisheries, which administers the affairs of the islands, there can be no question. Each deer killed is equal in food value to two sheep which are imported at about $15 per head on the average. Thus the equivalent of about 100 sheep was taken in 1921. The value of this food would seem to warrant the employment of capable herders and the erection of proper corrals for the care of the animals. This would not only enable the removal of the correct number of males without the uncertain method of shooting, but would enable the authorities to remove old and useless females, as any wide-awake stockman would do.

If the herds continue to increase during the next ten years as they have in the past ten, there should be about 2,500 deer on St. Paul Island in 1931 and about 1,600 on St. George. So large prospective numbers as these should receive care and attention, because the annual increment will furnish a supply of excellent

FIG 4 LICHENS KNOWN AS "REINDEER MOSS" FROM ST PAUL ISLAND, ALASKA

fresh meat, sufficient to supply all the needs of the islands for many decades.

Since the reindeer depend upon slow growing lichens, the familiar reindeer "moss," for food in winter, care should be taken that the herds do not increase beyond the supplies of these plants. The islands are small and not all of the surfaces are suitable for grazing by any means. It has been stated that this "moss" on the mainland of Alaska replaces itself in about seven years. Observations made by me on the Pribilofs indicate that there it grows more rapidly. Areas completely denuded in 1914 were regrown by 1919. The difference in rate of growth is believed to be due to the longer growing season on the Pribilofs and the much damper climate.

One of the most important problems to be solved in connection with the Pribilof herds is the determination of the maximum numbers which can be supported. The government should determine this before it is too late. With competent herders in charge of the animals it would not be a difficult undertaking.

These herds are under particularly fine circumstances for observation and study. The most distant part of either island can be easily reached in a day by a man on foot. Strict control is constantly maintained by the agents of the government; or at any rate it can be maintained when desired. More is known of the wild life of the reservation than of any similar area in our northern territory. It would seem that here is the place to maintain model reindeer herds and to determine many of the needed facts for the propagation of these animals on a large scale. At no other place are conditions so favorable. The animals have no enemies

on the islands. Dogs are not permitted to be landed and mosquitoes or other injurious insects are absent. By some queer but fortunate turn of fate, ticks or parasitic flies were not imported with the original shipment. No new stock has been brought in, so that inbreeding and crossing could here be studied to the greatest advantage.

It may be of interest to those who so vigorously opposed the introduction of the animals in 1911, and actually prevented it

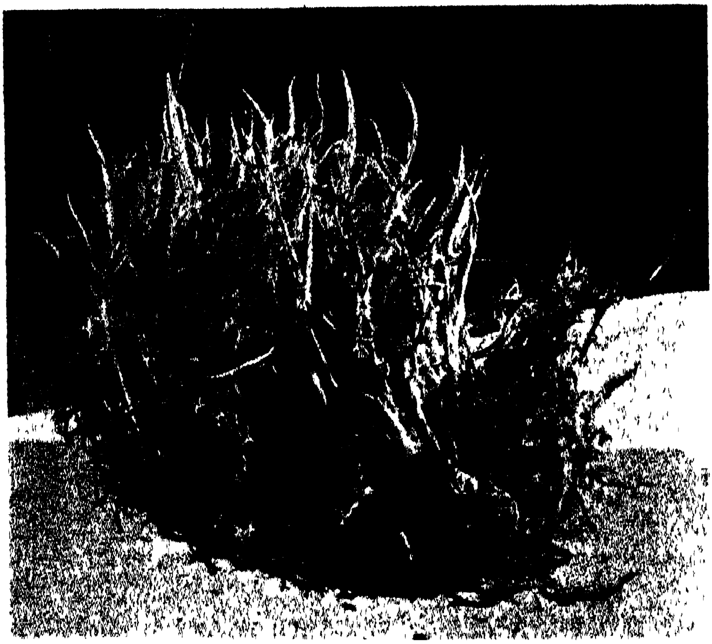


FIG. 5. LICHENS KNOWN AS "REINDEER MOSS." OTHER SPECIES, FROM ST. PAUL ISLAND, ALASKA

when first proposed by Ezra W. Clark back in 1905, to learn that the reindeer have not interfered in the slightest degree with the fur seal herds or with the work of securing their skins. The deer seldom visit the beaches and have not to my knowledge been observed on a fur seal rookery when it was occupied.

It is to be hoped that the Bureau of Fisheries will grasp the opportunity presented, and by careful study and care of its reindeer herds, furnish the people of Alaska with information which will be of inestimable value in the industrial development of the north.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson

Science Service

THE SCIENCE OF KEEPING COOL

The problem of hot weather is not, as some folks seem to think, how to keep the heat out. It is how to get the heat out. The body temperature sticks pretty close to the normal point of 98.6 degrees Fahrenheit and unless the air temperature gets above that we do not take on heat from the air.

For heat, like water, runs down hill It passes from a higher to a lower temperature The steeper the grade the faster the flow. That's where the difficulty comes in. For we have to keep our internal temperature at the normal point, whatever it may be outside, and there is only a thin skin and some clothes between When the weather is cold we have no trouble in getting rid of the heat we produce from the food we eat, for it runs off rapidly, so rapidly that we have to put on more clothes to check it. But as the air temperature rises nearer to that of our own the current of escaping heat slows up and finally sets back if the temperature goes over 99.

We shut down the furnace in our houses when winter goes. But we can not shut down the furnace inside of us because the works would stop. Our internal furnace serves as a power-house as well as a heater We have to keep the engine going night and day and that requires a certain amount of fuel, though of course we do not need so much in summer time.

A man who is not doing much, "just up and about," will have to have 2,400 calories of food a day. If he is working, he will need 500 or 1,000 more. So even if he lives in idleness he has to get rid of heat at the rate of 100 calories an hour on the average, which is about as much heat as is given off by four ordinary electric lights.

Now this heat can be got rid of in two ways. It can run away or be carried away. It will run away if the temperature of the surrounding air is enough lower than the body and there is enough, not too much, cloth between

It can be carried away by water. Water can carry more heat without showing it than anything else in the world A quart of water will take on a calorie of heat and only show a rise of less than two degrees Fahrenheit. When a quart of water evaporates it carries off about 500 calories. If, then, you sweat a quart this is the quantity of heat you are getting rid of, provided the perspiration evaporates from the skin Here is the difficulty If the air holds already all the water it can take up, then you can not get the benefit of the absorption of heat through evaporation So when the air is saturated with moisture, or, as the weather man puts it, when the humidity is 100, then you say "this is muggy weather" and you complain that the heat is intolerable even though the thermometer does not stand high.

Your own internal thermometer, your sense of temperature, only registers loss and gain. You feel warm when you are gaining heat. You feel cool when you are losing heat. You can only lose heat by radiation when the air is cooler than your skin. You can only lose heat by evaporation when the air is drier than your skin. It is only the layer next

ALFRED GOLDSBOROUGH MAYOR
In whose death biological science suffers a severe loss. Dr. Mayor was director of the department of marine biology of the Carnegie Institution of Washington

to your skin that counts. If the air there has a temperature of 99 degrees and a humidity of 100 per cent., then you can not get cool either way. In that case you must drive away the layer of hot moist air and let some that is drier and cooler get at your skin, which you can do by means of a breeze, or, in default of that, a fan.

GASOLINE AND ALCOHOL

BEFORE prohibition the per capita consumption of gasoline and alcoholic beverages was about the same, twenty gallons a year. Now the consumption of alcoholic beverages is theoretically reduced to zero while the consumption of gasoline has risen to seventy-seven gallons per capita.

But we may live to see these ratios reversed and gasoline decline while alcohol rises until vastly more alcohol is manufactured. For if alcohol comes into general use for fuel purposes vastly more must be manufactured than in the days when it was thought fit to drink. Now that the law will not allow us to drink liquor, we have alcohol to burn. And so soon as men get accustomed to regard alcohol as fuel instead of as food, the vexatious restrictions that

have been imposed upon its manufacture and sale for the last five hundred years may be removed. When that day comes the government will be urging people to set up home stills instead of confiscating them, and this will enable spoiled grain, unsalable fruit, sawdust and all sorts of wasted stuff to be converted into power on the spot.

For alcohol can be made out of more different things than almost anything else in the world, as those who have experimented with home brew have found out. Any sugary, starchy or woody material can be converted into alcohol, directly or indirectly, and there are millions of minute plants always hanging around ready to undertake the job of conversion for a bare living.

But if we have to shift from gasoline to alcohol we shall have to hunt for the cheapest and most abundant material to make it from, and it is high time that the hunting began. The saving of waste foodstuffs would not suffice. If we used corn it would take more than a quarter of our corn crop to make enough alcohol to take the place of the gasoline now used and we shall want to use more in the future as our desire for power increases.

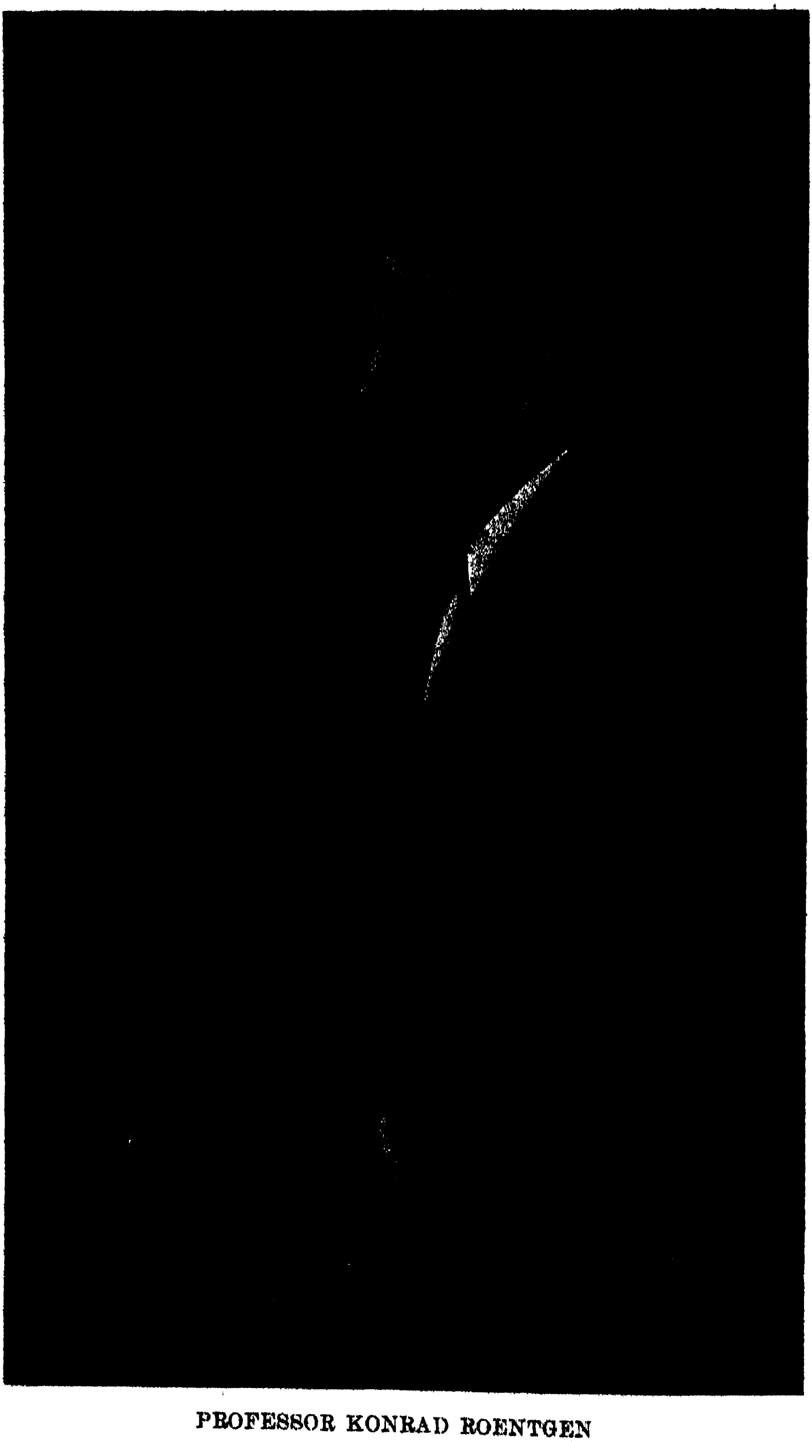
Probably it will be found that the tropics will grow the largest crops of saccharine material suitable for alcoholic fermentation in a season and, if so, this neglected region will assume the importance that the coal field countries now possess. There will then be hot strife for hot territory, and the alcohol power will rule the world. Dr. Diesel, believing that his engine using heavy oils—mineral or vegetable—would take the place of the gasoline engines burning light fluids like gasoline or alcohol, foresaw the time when palm, peanut or some other tropical oil would be the motive power on which civilization would depend.

There are, of course, many other conceivable possibilities. We may distill cellulose directly instead of converting it into sugar and then fermenting it to alcohol. The chemist may get up some carbon chain or ring with all the hydrogen it can hold that will make a better fuel than anything found in nature, but he will have to have something to make it out of and that something will have to be grown. Unless we find some other source of power than combustion, we must eventually grow our fuel as we use it, for fossil fuel will not last forever. We must find a way of using the sunshine of to-day instead of that which fell upon the earth in the Carboniferous Era.

FROM COMPLEXES TO GLANDS

How swiftly the spotlight of popular interest shifts from one part of the stage to another! The eyes of distressed humanity turn eagerly toward any quarter that appears to promise health and happiness. A few years ago psycho-analysis was all the rage. Now endocrinology is coming into fashion. Those who recently were reading Freud and Jung have now taken up with Berman and Harrow. Those who formerly were rushing to have complexes extracted are now anxious to have glands implanted. Away with psychology! 'Rah for physiology! Anything hailing from Vienna is bound to boom.

As fads there is not much to choose between them. Popular expectations always run far ahead of the march of sober science which must make sure of every step as it goes. Both these have a certain foundation of fact, and promise much for the future though neither can fulfill the anticipations of the public at present. But the scientific basis of the glandular idea is much more solid and substantial. An emotional



PROFESSOR KONRAD ROENTGEN

Who has retired from the chair of experimental physics at the University of Munich Professor Roentgen discovered the Roentgen or X-rays in 1895.

complex is after all a figment of the imagination, but when you get out a chemical compound, extracted, purified and identified, you have hold of something tangible and when you put it back into the patient you can regulate the dose and record the reaction.

Physiologists now lay many bodily disorders, as capitalists do industrial disorders, to the pernicious activity of "agitators." The physiologist, since he prefers to talk Greek, calls them "hormones" but the word means the same. At least a half dozen of these hormones are already known. They are marketed among the four hundred by-products of our packing houses. Two of them, thyroxin and adrenalin, are definite chemical compounds and can be made synthetically. Soon the chemist will capture them all and possibly he may make stronger and better ones than the glands turn out in their old-fashioned way. There may be giants on the earth in those days, such as Wells foretold in "The Food of the Gods."

These hormones determine our temper and our temperament. They decide whether we shall be tall or short, thick or thin, stupid or clever. They mold our features and control our characters. A minute amount of certain secretions will make one more masculine or feminine, older or younger.

But until the chemist can manufacture them in the laboratory and we can carry them in a vest pocket case, we are dependent upon more or less active and impure extracts from the glands to supply our functional deficiencies. Or—and this is the latest sensation of the hour—we may be grafted with a gland from some animal. Unfortunately, the glands of the lower animals do not set well in the human system. Those of the apes work best, which goes to prove that they are blood relations of ours, Mr. Bryan to the contrary notwithstanding. In any case the relief is not likely to last long, for the borrowed gland may succumb to the same influences that invalidated the natural organ.

In spite of the startling experiments of Voronoff and Steinach on the rejuvenation of rats and sheep, science is not yet in a position to meet the old demand for an elixir of life. Dr. Brown Sequard, of Paris, who thought thirty years ago that he had found something of the sort in an extract of goat glands, did not live long enough to demonstrate his discovery. The rich old man, who went to Vienna to regain his youth and came to London to prove the success of Steinach's operation, died on the eve of his lecture on "How I was made twenty years younger." But there will be plenty of people eager to try the new methods, urged by the same motive that drove Ponce de Leon to seek the fountain of immortal youth in the vicinity of Palm Beach.

SCIENTIFIC ITEMS

We record with regret the death of Alfred Goldsborough Mayor, director of the department of marine biology of the Carnegie Institution; of James McMahon, emeritus professor of mathematics at Cornell University; of Dr. Edward Hall Nichols, professor of clinical surgery in the Harvard Medical School; of Dr. W. H. R. Rivers, of the University of Cambridge, known for his work in anthropology and psychology; of Prince Albert de Monaco, distinguished for his oceanographic studies; and of Professor Edmund Weil, who died from typhus contracted by infection in his laboratory at Lemberg.

The John Fritz medal has been presented by the board representing the leading engineering societies to Senator Guglielmo Marconi. The medal is presented for achievement in applied science as a memorial to

John Fritz, who was the first recipient. Other recipients of the medal have been Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas Alva Edison, Charles T. Porter, Alfred Noble, Sir William Henry White, Robert W Hunt, John Edison Sweet, James Douglas, Elihu Thomson, Henry Marion Howe, J. Waldo Smith, George W Goethals and Orville Wright.

DR. GEORGE ELLERY HALE, director of the Mount Wilson Observatory and chairman of the National Research Council, has been appointed a member of the Committee on Intellectual Cooperation of the League of Nations, which was recently formed to promote research throughout the world and to facilitate the interchange of scientific information. Other scientific members of the committee are Professor Einstein and Mme. Curie.

THE American Museum of Natural History has had its endowment largely increased through contributions from John D Rockefeller, Jr, George F. Baker, and the settlement of the estate of Amos F. Eno The Rockefeller gift of $1,000,000 will make it possible for the museum to carry on its educational work throughout the city without impairing funds needed for scientific research. Mr. Baker's gift of $200,000 supplements a recent one of $100,000.

ARRANGEMENTS have been made to supply Russian men of science with the results of American scientific work accomplished since 1914. Under the chairmanship of Dr. Vernon Kellogg, secretary of the National Research Council, an American Committee to Aid Russian Scientists with Scientific Literature has been organized. Other members of the committee are Dr. L. O. Howard, chief of the Bureau of Entomology of the Department of Agriculture, Dr. David White, chief geologist, U. S. Geological Survey, and Dr. Raphael Zon, chief, forest investigations, U. S. Forest Service. This committee has arranged with the American Relief Administration to receive contributions of scientific literature at New York and transport them to Russia. It is a voluntary and temporary organization with headquarters at 1701 Massachusetts Avenue, Washington, D. C.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1922

THE REASONABLENESS OF SCIENCE[1]

By Professor W. M. DAVIS
HARVARD UNIVERSITY

A Fable of the Tides

ONCE upon a time—for science also has its fables—there dwelt a hermit on the shore of the ocean, where he observed the tides. He measured the period and the range of their rise and fall and, patiently tabulating his records, discovered that the tides run like clock-work. The interval between two high tides was determined to be about 12 hours and 26 minutes; the range from low water to high water was found to vary systematically, being greater one week and smaller the next, the total variation running its course in 14 days; more singular still, the high tides were found to exhibit an alternating inequality, such that, if they were numbered in order, the even-numbered would be stronger than the odd-numbered for two weeks and then the odd-numbered would be stronger than the even-numbered for two weeks; this cycle of alternating inequality completing itself in 28 days. The hermit then wishing to extend his observations, decided to travel overland to another ocean and learn whether the tides behaved in the same way there also.

Now at the same epoch, but far away in the center of a great continental desert, a recluse lived in a cave, thinking and reflecting. One problem in particular engrossed his thoughts. He knew Newton's law of gravitation, and he asked himself what other consequences ought to follow from it besides the revolution of the planets around the sun and of the moons around their planets. He at last convinced himself that if the earth and the moon attract each other, the moon must produce a system of what he called earth-deforming forces, disposed in such a way as to strain the earth's

[1] Oration delivered at the annual meeting of the Harvard Chapter of Phi Beta Kappa, in Cambridge, Mass., June 19, 1922.

crust, tending to raise it on the sides of the earth toward the moon and opposite the moon, so that at any one point on the rotating earth, the crust should be raised twice in a lunar day, or every 12 hours and 26 minutes; also, that similar but weaker earth-deforming forces produced by the sun should be combined with those produced by the moon so that the resulting total strains in the earth's crust would be stronger and weaker every 14 days; and furthermore, that as the moon is north of the sky equator for one half of a lunation and south of it for the other half—Alas, that you dwellers in roofed houses are so little acquainted with the sky as not to know of your own seeing that the moon's course does carry it obliquely across the sky equator and back again every month!—but as the moon does move in this manner, the recluse saw that the deforming forces which tend to raise the earth's crust at any point must exhibit a sequence of alternating inequalities every 28 days. And beside these rhythmic variations in a little more than half a day, in 14 days, and in 28 days, he worked out several other variations of even longer periods. But his calculations also showed that the rhythmic forces were too weak to deform the stiff earth's crust perceptibly. "If only," he thought to himself, "some large part of the earth's surface were covered with a deep sheet of water, surely the deforming forces would make the yielding water sheet rise and fall every 12 hours and 26 minutes, with a variation of range every 14 days, and an alternating inequality of rise every 28 days, and so on." He thereupon resolved to travel into other regions and learn, in case a vast sheet of water were anywhere discovered, whether it really did exhibit rhythmic changes of level in systematic periods such as, according to his calculations, it ought to exhibit.

Observation, Invention and Deduction

Curiously enough it happened that about this time the hermit reached a caravansery where he met an alert-looking individual who proved to be an inventor—not an inventor of machines but of hypotheses and theories and explanations. The hermit told him about the tides and their periodic variations, and asked: "What do you suppose makes them go?" The inventor thought a moment and then said: "Perhaps the tides rise and fall because Old Mother Earth is slowly breathing; or perhaps, inasmuch as you say the tides vary every 12 hours and 26 minutes, or twice in a lunar day, they may possibly be driven by the moon." "How can they be driven by anything that is so far away in the sky, and why should one moon make two high tides in one lunar day?" asked the hermit. Just then the recluse came in and, approaching the other two, inquired: "Can you tell me whether there is any-

where a vast sheet of water covering a large part of the earth?" "Yes, there is," said the hermit; "it is called the ocean. I have lived on its shores, observing the periodic rise and fall of its waters in the tides and I was just asking the inventor here if he could tell me how they are caused." The inventor repeated his suggestion that the tides might possibly be caused by a sort of earth-breathing, but that they were more probably caused by the moon. "Well, as to that," exclaimed the recluse, "I can tell you how the tides ought to run if the moon has anything to do with them. The moon ought to produce two high tides on opposite sides of the earth, so that as the earth rotates, the tides at any one point ought to rise and fall twice in a lunar day, as you say they do; not only so, they ought to be extra strong every 14 days at new moon and at full moon, because the sun also must have a share in producing them; and besides that, the high tides ought to show an alternating inequality in a period of 28 days; and"—The astonished hermit interrupted—"They do exactly that," he cried, "but how in the world did you know they do so, if you have never seen the ocean?" "I didn't know they did," replied the recluse, "but I was convinced that *if* the earth had an ocean its waters ought to have rhythmic oscillations of the kind I have described, because don't you see——" and he proceeded to explain his calculations.

VERIFICATION

"What are you men talking about?" said a sedate-looking onlooker of judicial aspect. So the hermit, the inventor and the recluse all repeated their stories to him. He pondered a while and then remarked to the inventor—"It looks very much as if your hypothesis about the moon's driving the tides were correct, for it is hardly conceivable that the consequences of lunar attraction, as thought out by the recluse, and the period of the tides, as observed by the hermit, could agree so well unless the moon and the tides stood in a veritable relation of cause and effect; but the hypothesis needs modification because, as the recluse has pointed out, the secondary variations of the tides show that the sun also has something to do with them." "But," interposed the recluse, "there should be, besides those already mentioned, still other periodic variations in the tides if they are really caused by the moon and the sun, and it will demand of the observer at least a year to detect some of the longer ones." "Take your time," said the judicial onlooker, "go back to the ocean and make a long series of records, not only at one point but at many different points on widely separated coasts; and come back here for a second conference 10 or 20 years hence. We may then reach a well established conclusion."

And thus it came to pass that, after long series of tidal observations had been made in many parts of the world, all the rhythmic consequences deduced from the moon-and-sun theory were so fully confirmed by their correspondence with the observed periodic variations of the tides in the ocean, that—in short, it all ended happily: all the world was convinced that the moon and the sun really do drive the tides.

The Four-Faculty Procedure of Modern Science

But the moral of the fable is yet to be told. The moral is that the observant hermit, the alert inventor, the thoughtful recluse, and the judicial onlooker represent not four different individuals, but only four different mental faculties in a single individual, the trained man of science, who uses his powers of observation to discover the facts of nature, his inventive ingenuity to propose various possible hypotheses for the explanation of the facts, his power of logical reflection to think out, or deduce, from each hypothesis, in accordance with previously acquired, pertinent knowledge, just what ought to happen if the hypothesis were true, and his impartial faculty of verification to decide which hypothesis, if any, is competent to explain the observed facts. In view of the leading part taken by these four faculties in scientific investigation, we may speak of science as involving a four-faculty procedure. But the fable must not be taken to mean that every scientist has all his faculties developed to the full strength needed for the best work; one man may be a patient observer but not active-minded enough to be a good inventor of hypotheses; another may be an ingenious inventor of hypotheses, but too impatient to be a good observer and too flighty to be a good deducer, and so on. Nor must it be understood that the several faculties work independently; as a matter of fact, now this faculty, now that is called into play in irregular sequence, and very frequently they are summoned into conference with one another. If it were not that the phrase is preoccupied in another connection, we might call such conferences "faculty meetings." Furthermore, it must be pointed out that replacement of mental deduction by experiment is essential in problems of certain kinds; that is, the faculty of invention is called upon, after proposing an explanatory hypothesis, to devise special artificial conditions under which natural processes shall themselves be permitted or constrained to determine the consequences of the hypothesis; but mental deduction usually accompanies or follows experimentation, and therefore problems into which experiment enters may still be included under four-faculty science.

The Fallibility of Science

Unfortunately, in all steps of science from observation to verification, mistakes may be made, errors may creep in. It would be profitable to examine some of the more common classes of errors into which scientific investigators are led by the imperfection of their faculties; and it would be still more profitable to set forth the safeguards by which the danger of making errors may be lessened. Brief comment on observation and verification may be made in these respects. Errors commonly associated with observation result from the unconscious extension of visible things into inferred things, and from the attempt to establish generalizations on too narrow a basis. Consciousness of the danger of these errors goes far toward eliminating them. The most common errors associated with verification are a tendency to adopt an imperfectly supported conclusion instead of maintaining a suspended judgment, and an unwillingness, indeed an inability to change an adopted conclusion after it has been invalidated by new evidence.

As to the latter cause of error it may be said that, if proficiency comes from practice, it would be almost worth while occasionally to lead advanced students to a false conclusion and leave them in it for a time, so that they might have actual practice in changing their minds when corrective evidence is later brought forward. Indeed, scientific training can hardly be regarded as completed until it has included the necessity of giving up a cherished opinion. The experience is distinctly an unpleasant one; it causes mental disturbance to the point of sleeplessness; but it is profitable in promoting the maintenance of a mobile state of mind. Time forbids further consideration of this aspect of scientific methods; but I must again emphasize the undeniable and regrettable fact that, in spite of all efforts in training and safeguarding the mental faculties, it is still impossible to avoid all errors, because scientists are fallible; for if mistakes can be made with respect to anything so manifest as visible facts of observation, they are still more likely to be made when it comes to the invisible facts of theory. The marvel is not that mistakes of both kinds are made, but that, in spite of man's undeniable fallibility, so great a body of scientific conclusions still holds good, especially with regard to what I have just called the invisible facts of theory. Let me say a few words on that point.

The Nature of Theorizing

There is a popular prejudice against the use of the inventive faculty, ordinarily called theorizing. Theorizing alone, mere theorizing, is certainly of little value; but trained theorizing in

proper association with trained observing is absolutely essential to scientific progress. The chief reason for this is that our observing senses are of limited power. We soon reach the conviction that many facts of nature elude direct observation, either because their medium is inherently transparent and intangible, or because their dimensions are submicroscopic, or because their time of occurrence lay in the irrecoverable past. And yet all of these unobservable phenomena are in their own way just as much a part of the natural world as observable phenomena are. If we wish really to understand the natural world, surely those of its phenomena which are not immediately detectable by our limited senses must be detected in some way or other; and the way usually employed is—theorizing. No single observable fact is a complete entity. The world is not so simply constituted. The deeper one inquires into the nature of an observable present-day fact, the more one becomes persuaded that it is in some way or other related to something else that, for the reasons just given, is not observable; and in such an inquiry one soon becomes convinced that the something else is, in spite of our not seeing it, or hearing it or feeling it, in short not sensing it, just as truly a fact of nature as the sensible fact from which our inquiry started out. The sensible facts are discoverable by our senses, the insensible facts by our thoughts. The invention of hypotheses is therefore nothing more than a mental effort to bring insensible facts into causal relation with sensible facts, and such an effort of correlation is praiseworthy even if it is daring.

Now hypotheses when first invented are as a rule not only incomplete, but are also without assurance of being true, especially with regard to insensible facts. Of course they must explain the observed facts that they were invented to explain; they would deserve no consideration at all if they did not do that! But before any one of several competing hypotheses is accepted as true, it must do more; it must explain facts that it was not invented to explain, facts that were perhaps not known when it was invented; and it must do this consistently with all previously acquired knowledge, so that the new explanation shall cohere with the older ones. Not until these exacting demands are satisfied should the correctness of even the best of several competing hypotheses be accepted. It therefore remains, after several hypotheses have been invented, to determine which one of them, if any, is right; that is, to determine whether the imagined insensible facts of any one of the hypotheses are truly counterparts of actual insensible facts. That important task is accomplished, as was shown in the tidal problem, by mentally deducing all the logical consequences of each

hypothesis and then matching them with appropriate sensible facts. If the consequences of a hypothesis are numerous, peculiar and complicated, and if, even so, they succeed in matching equally numerous, peculiar and complicated facts, a good share of which were unknown when the hypothesis was invented, then it is highly probable that that hypothesis is true.

Let me add that it is this demand for the verification of a hypothesis after its invention that especially distinguishes modern science from primitive science, as I shall later show more fully; and it is chiefly because of the demand for verification that the modern progress made in the daring search for insensible facts has been so great. Errors are still made, because scientists are still fallible; but instead of pointing, I will not say the "finger of scorn," but the thumb of reproach at science for having made and for still making errors, we should rather marvel at its successes, particularly in revealing to us the nature of the unseeable, insensible world, as in the inconceivably small subatomic electrons and ions which enter into the composition of the material substances of the world; or in the existence of the marvellously tenuous, elastic, and immaterial medium, named the luminiferous ether, by which radiant energy is conveyed through what we call empty interplanetary and interstellar space; or in the event of the past history of the earth's surface, which were visible enough in their time, but which are now irrecoverably invisible.

The Credulity of Science

It is not to be denied that much credulity is called for in this daring search for the unobservable facts of the natural world. Science, however, is not alone in credulously building up an unseen world to complement the seen world. That has been done by non-science also for ages past. But the credulity involved in the two cases is unlike. In the latter the credulity is whimsical, fantastic, irresponsible, incoherent; in the former it is orderly, controlled, rational, coherent. During the progress of the human race from savagery toward enlightenment, fantastic, incoherent credulity is slowly replaced by rational, coherent credulity. The belief in witchcraft is a good example of irrational credulity. Let me give you an equally good example of rational credulity. The solution of the tidal problem involves a belief in the force of gravitation, by which two bodies like the moon and the earth or the sun and the earth exert a pulling force upon each other. We are familiar with the exertion of a pulling force through material substance, as when one pulls a heavy body with a rope; but the attraction of the sun upon the earth is exerted through what appears to be empty space. Yet in spite of the absence of anything to pull with, the

sun's attraction is strong enough to pull the moving earth continually into the curved path of its orbit. How large a rope or cable do you suppose would be required to represent, in material form, the pull exerted through empty space by the sun on the earth? If the cable were made of ordinary telegraph wires, the wires would have to be planted all over the earth's disc about as close together as grass roots in a lawn, and even then the wires would be stretched almost to breaking strength in compelling the earth to turn from a straight tangent into its curved orbit. Scientific credulity accepts that marvel. It believes that that enormous pull is exerted by the sun on the earth through space that is empty of all material substance, even though no adequate physical explanation is yet found as to how the pull can be exerted. Credulity of a certain kind is therefore highly characteristic of science and of scientific men; it leads them to believe marvels quite as marvellous as any that were ever believed in unscientific ages.

The Scheme of the Geographical Cycle

Let us now turn to an altogether different example of scientific inquiry, a geographical inquiry concerning the distribution of plants and animals over the earth's surface. Climate is an important factor in controlling their distribution. Now climate varies not only from equator to pole but also with altitude above sea level. Lowlands are warmer and as a rule drier than highlands. But a lowland may, it is believed, be changed to a highland by the gradual upheaval of its part of the earth's crust; and it is believed further that a highland thus produced must in the course of time be worn down to a lowland again by the still more gradual processes of erosion. A warm lowland with a moderate rainfall may therefore be upheaved into a cool or cold highland with greater rainfall; and after the forces of upheaval have ceased, the cool and rainy highland may be very slowly worn down to a warm and less rainy lowland again. Evidently there must be changes in the flora and fauna of a region while it is undergoing these changes of altitude and of climate. As a lowland is raised into a highland and its climate modified, its former flora and fauna can not survive, because they can not accommodate themselves to the new climatic conditions. They are therefore replaced by immigrants from some neighboring highland or from some lower land nearer the pole. Likewise the occupants of a highland can not survive the changes of climate that take place as it is worn down to a lowland; they are therefore gradually replaced by invaders from some other lowland not too far away. It is instructive to note that these changes of the earth's surface, slow as they may be, are faster as a rule than the evolutionary changes of plants and animals. Hence, in

a long view of the earth one would see its plants and animals not only undergoing their extremely slow evolutionary changes, but also making somewhat less slow migrations, prompted by and accompanying the upheavals and down-wearings of its surface; and the present distribution of plants and animals is believed to be simply a transitory phase in this long succession of changes.

How different is this problem of the cycle of geographical changes from that of the tides. The rapid changes of the tides are directly observable; they are moreover periodic and their changes can therefore be observed over and over again; and both they and their cause are susceptible of quantitative mathematical treatment. The changes of the geographical cycle are so slow that they can not be followed, they can only be imagined; and there is no reason for believing that such cycles of change are accomplished in a definite period, nor indeed that any given cycle will run its entire course without disturbance; the downwearing of a highland to a lowland may be interrupted during its progress by a new upheaval. Moreover the asserted extinctions and invasions of plants and animals following the changes in the climate of their habitat are only inferences. In a word, this scheme of the geographical cycle is in its very nature highly speculative. Why then should credence be given to it? For the very simple reason that only by believing it can a host of present-day observable facts, inorganic and organic, be brought into reasonable relations. In short, the scheme of the geographical cycle is believed because it works; and therefore, like many other scientific conclusions, it is an excellent example of pragmatic philosophy. But how venturesome is a scheme in which the observed facts of to-day constitute so small a fraction of the total phenomena! On the other hand, for those who have the scientific faith to believe that such changes as those involved in the scheme of the geographical cycle have actually taken place in the evolution of the present aspect of the earth, how admirably does this scheme give us examples of invisible facts of theory! And in spite of their being deeply buried in the past, how wonderfully are those facts recovered, at least in their general nature, by taking that mental action which, although it does not add a cubit to our physical stature, does add immensely to our understanding.

The Nature of Scientific Demonstration

But what does a man mean when he says that he believes the scheme of the geographical cycle, with its imagined yet unseen changes of land forms and its inferred yet unobserved changes in the distribution of plants and animals. He ought not to mean that the truth of the scheme has been absolutely proved, but only

that it has been given a very high order of probability; for that is, as a rule, the nature of what is often called scientific demonstration. He ought to recognize also that many generalizations on which the argumentation of the scheme rests are likewise not absolutely proved: for example, the persistence of the present-day order of natural processes through hundreds of millions of years of past time; to says nothing of the unbroken continuity of time itself! Who can prove the truth of those generalizations in any absolute sense? Nevertheless one accepts their truth because he finds, after due inquiry, that they too appear to have a high order of probability.

Now what is the common feature in the problem of the tides and the problem of the geographical cycle, and in all other scientific problems, in virtue of the possession of which they deserve to be called scientific? Evidently not the subjects that they treat, for the subjects of scientific study are remarkably diverse. The common feature inheres not in the content of the problems but in their method; and the common feature of their method is the quality of reasonableness; that is, a spirit of free inquiry, in which no prepossessions are accepted which are not themselves open to scrutiny, in which the conclusions reached are followed wherever they lead, and in which a revision of conclusions is made whenever it is demanded by new facts. Science is therefore not final any more than it is infallible. It is a growth, and its growth is by no means completed.

Science had indeed only very gradually grown to be the four-faculty procedure that it now is. In very primitive times the mere observation of facts without inquiry as to cause was perhaps as far as science could then be carried; it was only a one-faculty procedure then. Somewhat later simple generalizations regarding facts that resembled each other may have been made; and the generalizations framed by individuals may have advanced to tribal generalizations. Indeed it seems quite possible that some such tribal generalizations of one-faculty science, for example, as to things that are good and bad to eat, may have been established by our anthropoid ancestors before they deserved to be called men. But even the most primitive tribes of men now living seem centuries ago to have advanced into a second stage of two-faculty science, in which the invention of explanatory hypotheses is added to observation and generalization. Even the lowest savages now known try to explain many of the things that they see by relating them to other things that they either see or do not see, and they thus establish to their own satisfaction relations of cause and effect. If the effect is explained by a visible cause, well and good. But if,

in the stage of two-faculty science, the effect is explained by an invisible cause, what then?

The Two-Faculty Procedure of Primitive Science

In striking contrast with present-day four-faculty science in which verification is so essential, the earlier two-faculty stage of science accepts its hypotheses without any adequate verificatory inquiry. Its explanations do not have to explain more than they were invented to explain, and they do not have to cohere with previously acquired knowledge. If they explain the facts that they were invented to explain, that is enough. Naturally therefore the two-faculty stage of science represents a phase of human development in which whimsical, incoherent credulity flourishes, the kind of credulity which I have already referred to as unscientific, because it is so unlike the orderly, coherent credulity of four-faculty science. But I now wish to treat that incoherent credulity in another way; to regard it as the inevitable accompaniment of two-faculty science, and hence just as appropriately an element of an early stage in the evolution of science as the rational, coherent credulity is of the present, more advanced stage. It is as if, between the primitive one-faculty stage, which was reasonable as far as it went, and the present four-faculty stage which seems to those who have reached it completely reasonable, there had been an unreasonable two-faculty stage in the evolution of science. The three stages are so unlike that one might hesitate to call them all scientific; just as one hesitates to give a single name to a caterpillar, a chrysalis and a butterfly: and yet the first two stages are in both cases the essential antecedents of the third. In any case the two-faculty stage of science was as reasonable as the two-faculty scientists could make it; and that is all we four-faculty scientists can say of our own stage.

The Natural History of Goodness

This may be made clearer by illustration. At the opening of my address I outlined the problem of the tides as one which modern four-faculty science has carried to a well established quantitative solution. This was followed by the problem of the geographical cycle which, although avowedly very speculative, has been advanced to a qualitative solution at least. I wish now to consider a third problem, which illustrates remarkably well the gradual development of inquiry in ancient times, and also the difference of certain conclusions reached by two-faculty science that was in vogue then from those reached by four-faculty science that is current now; and this problem has the further value of illustrating the optimism of science, for it leads to a conclusion concerning mankind that is

full of hope. The usual name for the subject of this third example is the science of ethics; I propose, however, to call it in general terms the natural history of goodness. There is nothing new in what I have to say on this old subject, although I may give a new emphasis to some of its aspects.

The facts which this branch of natural science treats are found in the body of opinion held by the different tribes and peoples of the world concerning things which they regard as right and wrong, that is, in their moral codes, and in the actions which they approve or condemn. Different people have different codes, and the code of the same people changes with the passages of time. Countless are the tragedies that have been enacted when a more powerful people, arrogantly assuming the justice of its own code, has ruthlessly violated the code of a weaker people. The theoretical side of the science includes a search for the sources of the different elements of each tribal or national code, for the processes by which the elements of a code are slowly modified, and for the forces by which good thoughts and acts may be fostered and bad ones suppressed. The natural history of goodness is therefore concerned with the concrete opinions and actions of ordinary men in commonplace, every-day life, and has nothing to do with the abstractions of metaphysics regarding absolute and eternal ideals. In that respect it might be compared with the natural history of mathematics, which would portray the efforts of early man in gradually and tentatively developing the multiplication table, but would have nothing to do with the metaphysical pre-existence and everlasting verity of 7 times 9 being 63. For in the same way the natural history of goodness would, if it could, describe the first recognition and the later modification of various ethical principles by certain peoples in certain places at certain times under certain conditions, but it would take no acocunt of the metaphysical view that all ethical truths are eternal, as if they had existed by themselves somewhere in the interstellar spaces of the universe for untold ages awaiting recognition.

The Ethics of the Children of Israel

The few illustrations of this great subject that I have time to present will be taken from the Old Testament, that marvellous record of the intensely human struggle made by a primitive and ignorant people in their advance from savagery to barbarism. How very primitive they were; and in no way more primitive than in candidly recording their frequently scandalous behavior! A more sophisticated people would have taken care to conceal their errors, but the Children of Israel were savagely naïve. Their early books,

those of the Pentateuch and the ones next following, contain abundant material for study in announcements concerning things held to be right or wrong as affecting food and hygiene, property in land, cattle and slaves, safety of life and limb, and social intercourse. The good things are sometimes directly stated, but they are more often to be inferred as the opposites of bad things that are prohibited or punished.

None of the announcements are more striking than those which have to do with the taking of human life as a punishment for various kinds of wrong-doing. In the time of Noah this important problem was treated simply and concisely: "Whoso sheddeth man's blood, by man shall his blood be shed" (Gen. ix, 6). But that early pronouncement was elaborately modified in the time of Moses and afterward. It was then still ordained in general terms that "thou shalt give life for life;" but it was also ordained on the one hand that, besides offenses of bloodshed, various other offenses should also be punished by death, and on the other hand certain offenses of bloodshed should not be punished by death. As to the first, a number of offenses are listed, among them being for example the smiting or the cursing of one's father or mother, for which a man "shall surely be put to death" (Ex. xxi, 12-17); and here the use of the word "surely" seems to imply that the Children of Israel were sometimes too lax in the punishment of such offenders. As to the second group of offenses, a time came when careful distinction was made between intentional and accidental manslaughter. Thus if one man thrust another out "of hatred, or hurled at him, lying in wait, so that he died," that man is a manslayer and "the avenger of blood shall put the manslayer to death, when he meeteth him." This command is emphasized by the suggestive addition: "Ye shall take no ransom for the life of a manslayer (Num. xxxv, 20, 21, 31). But a man who "killeth his neighbor unawares, and hated him not in time past; as when a man goeth into the forest with his neighbor to hew wood, and his hand fetcheth a stroke with the axe to cut down the tree, and the head slippeth from the helve, and lighteth upon his neighbor, that he die;" then the man is not worthy of death, inasmuch as he hated not his neighbor in time past (Deut. xix, 4, 5, 6). At an early time one witness seems to have been sufficient to prove a man to be a manslayer; but in later time it is said: "At the mouth of two witnesses or three witnesses, shall he that is to die be put to death; at the mouth of one witness he shall not be put to death" (Deut. xvii, 6). What good, homely common-sense this is!

Ancient and Modern Views of Israelitic Ethics

It would appear from these and many other passages, especially those concerning their wars, that the Israelites must have been in-

deed a violent crew; but it appears also that they made very explicit and frank record of their views concerning right and wrong. Now if we examine their records as contributions to the natural history of goodness in an era of two-faculty science, we ought to ask ourselves among many other questions, not only what were the views of the Israelites concerning good and evil, but also how they gained their views, and how they came to establish, as a means of controlling their actions for the common weal, rewards for good and punishments for evil. As a matter of fact, investigation of this large subject has been carried on earnestly for a century or more, and in a truly scientific spirit; that is, reasonably and with an open mind. I propose to compare, or rather to contrast, the conclusions reached by modern students of the subject under their four-faculty procedure, with the opinions held by the Israelites themselves under their two-faculty procedure.

The Israelites' view was, if we are to take their records literally, that their understanding of good and evil as well as their decrees for the reward of good and the punishment of evil, came to them by supernatural revelation; and this view was adopted by all Christendom in later centuries. The modern view, more and more widely adopted now, is that the Israelites derived their knowledge and their decrees concerning good and evil in a perfectly natural way from a perfectly natural source; namely, from their own perfectly natural experience, the same source from which all other human knowledge is gained. The decrees and commandments were not sudden acquisitions, but merely expressions of the morals and customs gradually developed among the people and formulated by their leaders. In comment upon these two views it should be noted that the ancient view originated among a primitive, ignorant, cruel, self-centered people, very ready to adopt extraordinary, even supernatural explanations for simple occurrences, because being in the stage of two-faculty inquiry they did not apply, they did not know how to apply independent verificatory tests to their hypotheses, but naïvely believed them if they explained the things they were invented to explain; and that the modern view has been gradually developed in later times by many broadly informed students of human history and human nature, who have gathered a vast amount of information not only about the ancient Israelites but also about many other primitive peoples, ancient and modern; students who have examined that information reasonably and in a spirit of free inquiry, who have at every step in their inquiry done their best, according to the procedure of four-faculty science, to verify their explanations and who have therefore reached their conclusions carefully and critically, intelligently and sympathetically.

Grounds of the Modern View

Some persons here present probably hold the earlier one of the two views, and some the later one; but however my audience is divided in that respect, it is more likely a unit in not habitually looking on the Old Testament as affording material for the scientific study of the natural history of goodness, and as therefore not regarding it as affording fit illustrations for the third example of scientific inquiry, which I am now outlining. There seem nevertheless to be cogent reasons for looking on it in this way. One of these reasons is that the Old Testament, especially its earlier half, gives so excellent an idea of the manner of life led by the Children of Israel. The records are as a whole unconcealedly human in telling of friendships and quarrels, of generosities and meannesses, of honorable acts and of dishonorable acts; hence they give an invaluable picture of the views of a primitive people on moral questions.

Furthermore, when the books of the Old Testament are read—particularly when they are read in a polychrome edition which distinguishes the various sources from which the successive books are compiled—the understanding of good and evil there recorded is seen to exhibit very distinctly an evolutionary progress, such as is found from studies of other peoples to be characteristic of the natural history of goodness in general; witness the citation already made about manslaughter; witness also the declarations concerning food. In the time of Noah it was said: "Every living thing shall be good for you" (Gen. ix, 3); and this is much more primitive than the later declaration in the time of Moses, when sharp discrimination was made between the cloven-footed, cud-chewing animals which might be eaten and other kinds of animals which might not be eaten (Lev. ix; also Deut. xiv). It may be noted in passing that a belief in the evolutionary development and progress of mankind greatly simplifies the vexatious problem of the existence of evil in the world; for much of the forbidden behavior or wickedness of a later era is thus seen to be only a continuation of the permitted behavior of an earlier, less advanced era.

Finally, the Old Testament records of the Children of Israel may be taken as affording proper material for the study of the natural history of goodness because they show the Israelites to be so very like other savage races. They justified themselves as a chosen people; they ascribed bad qualities to their enemies whom they really resembled rather closely; they saw mysterious omens in commonplace events; they regarded dreams as messages from an extra-human source; they were miraculously visited by good and bad spirits; they took their own very human convictions to be revelations and commandments from their local tribal god; and

to that god they attributed, but in a higher degree, their own very human qualities; not only wisdom and goodness and power, but also forgetfulness, repentance, hatred and revenge. In all this the Children of Israel are so like other primitive tribes that they must evidently be studied just as other primitive tribes are studied.

Supernatural and Natural Interpretations

Now in reviewing the reasons thus briefly set forth for regarding the records of the Old Testament as affording fit material for the study of the special branch of human evolution here under consideration, it is interesting to notice that the same reasons lead to the rejection of the older view that the knowledge of good and evil gained by the Israelites was derived from a supernatural source, and to the acceptance of the modern view that it was simply a summation of their own human experience. Indeed, when the Mosaic books are read in a rational, scientific spirit, without prepossession, the marvel is that they can be interpreted in any other way. That the Israelites should have introduced supernatural elements into their records, as when they explained the Ten Commandments by revelation, is inevitable in view of what is now known concerning the natural history of goodness among all primitive peoples in the stage of two-faculty science; and that they should have accepted these supernatural elements as true is thoroughly characteristic of the incoherent credulity that prevails among primitive peoples under the two-faculty method of establishing beliefs in unseen things. But that the supernatural elements of these ancient and primitive beliefs should have been accepted as true by all Christians during nearly all the centuries of Christendom is nothing less than marvellous; or perhaps I should say, would be nothing less than marvellous did we not know that through all those centuries a great part of the beliefs of Christendom were dominated by two-faculty science.

Consider, for example, the decree concerning a servant who has earned his freedom by six years of service, but who then still loves his master, his wife and his children so much that he does not wish to go out free and leave them: in that case "his master shall bring him . . . to the door, or to the door post; and . . . shall bore his ear through with an awl; and he shall serve him for ever" (Ex. xxi, 6). Boring a hole through a man's ear with an awl would seem to be a very simple, a very human way of marking him. It is therefore unduly credulous to believe that this and other similar decrees had a supernatural source, even if they are preceded by the introductory statement: "And the Lord said unto Moses, these are the judgments which thou shalt set before the Children of Israel" (Ex. xxii, xxiii). No such introductory statement is

given before similar decrees in Deuteronomy xv. One is indeed tempted to think that the words, "And the Lord said . . . " by which various paragraphs in the Pentateuch open, were hardly intended to be taken literally.

The Treatment of Enemies

If anything more is needed to show the utterly human nature of the Mosaic decrees, it is found in the narrow limitation of the commandments: "Thou shalt do no murder . . . Thou shalt not steal," for manifestly these rulings applied only to neighbors and fellow tribesmen, not to enemies. As to enemies, commands were repeatedly given, as if from the Lord, to kill them wholesale, even to their women and children; and to steal from them everything they possess. The advance of the Israelites to the promised land under Moses and Joshua is a horrible story of rapine and bloodshed; the plain and pitiless story of ruthless savagery. Samuel is probably remembered by most persons nowadays chiefly as a gentle little boy, who, wakened from his sleep by the call of the Lord, answered, "Speak, for thy servant heareth" (I Samuel iii, 10); yet it was Samuel who, when grown to manhood, was possessed with the idea that the Lord gave him a message, a hideous message, to Saul, to smite the Amalekites "and utterly destroy all they have, and spare them not; but slay both man and woman, infant and suckling, ox and sheep, camel and ass." And because Saul and his army, after killing every man and woman, infant and suckling, spared Agag the king of the Amalekites and kept the best of the oxen and sheep for themselves, "then came the word of the Lord unto Samuel, saying, It repenteth me that I have set up Saul to be king . . . and Samuel was wroth" and had Agag brought before him and hewed him in pieces with a sword (I Samuel xv, 3, 11, 33).

A Great Debt to Science

We have sadly to admit that horrors of those kinds have been frightfully characteristic of human progress from savagery and barbarism all over the world; and also that such horrors have been frequently regarded by the people who committed them as acceptable to or directed by their local tribal deities, as they conceived them; but it must have been a heavy burden to Christian faith to believe that the loving, fatherly God of the New Testament is the same god who led Joshua in his bloody wars and who told Samuel to give that hideous message to Saul. It is a great blessing that the progress of modern scientific inquiry and the spirit of rationalism that has grown with it have relieved Christian faith of that burden. Science has truly benefited the world in many ways, but it may be doubted whether any other benefit derived

from scientific rationalism is so great as the liberation of Christianity from the reproach which it fully deserved so long as it included a literal acceptance of all the teachings of the Old Testament, in spite of Christ's preaching a religion of brotherly love in the New Testament.

But you may ask, is it truly to science that the world owes that great benefit? Has science indeed anything to do with these religious matters? It has of course to do with the earth and the stars, with plants and animals, with steam and electricity; but by what right does science concern itself with questions of good and evil? It does so by the same right, precisely the same right that it studies the tides as governed by the moon and the sun, and the slow changes of earth's surface when lowlands are raised to highlands and when highlands are worn down to lowlands. For the observant and thoughtful study of mankind discovers many facts of opinion and facts of action concerning things that are regarded as good or bad, and all those facts, which together with their causes and consequences are included under the natural history of goodness, are just as properly open to scientific inquiry, that is, to unprejudiced, reasonable inquiry, as any other facts in the world. Nevertheless, the feeling that science is a trespasser on such ground is often met; and also the allied feeling that science is too cold and hard to deal with such questions. Let us see.

THE CONFLICT OF RELIGION AND SCIENCE

First, as to science being a trespasser when it touches questions with which religion has traditionally dealt. Much has been written about what is called the conflict between religion and science. The cause of that conflict lay not in the trespass of science upon the proper field of religion, but in the trespass of religion upon the proper field of science. Religion attempted, while thus trespassing, to dictate beliefs concerning the age of the earth, the origin and the antiquity of man, and many other mundane matters. What is more natural than that science, as it developed, should enter into conflict with the trespasser; and what more manifest now than that, in so far as geology and organic evolution and other similar subjects are concerned, the conflict should have resulted in the complete conquest of those subjects by science from religion! This wholesome defeat of religion, or rather of the misguided defenders of what was long thought to be religion, would not have taken place had the advice of St. Augustine been followed. He wrote long ago: "It very often happens, that there is some question as to the earth or sky, or the other elements of this world . . . respecting which one who is not a Christian has knowledge derived from most certain reasoning or observation, and it is very disgrace-

ful and mischievous and of all things to be carefully avoided, that a Christian speaking of such matters as being according to the Christian Scriptures, should be heard by an unbeliever talking such nonsense, that the unbeliever perceiving him to be as wide of the mark as east from west, can hardly restrain himself from laughing" (Thus quoted in Osborn's "From the Greeks to Darwin").

Will not a modern St. Augustine arise and make a similar statement concerning the natural history of goodness? I wish he would, for all human thoughts and acts are, like human anatomy and physiology, the product of natural evolution. Just as surely as all questions of a geological or astronomical or biological nature have now been permanently acquired from religion by their respective sciences, so conquest will be made of all questions concerning right and wrong by that division of science which concerns itself with the natural history of goodness as a matter of purely human experience, in contrast to goodness as a matter of supernatural revelation. Two great and growing, though still young branches of modern science will contribute powerfully to this conquest; they are eugenics and psychiatry. I hope that some speaker before this society a hundred years hence will review the practical contribution by that time made to human betterment by these young giants.

True Science is neither Cold nor Hard

As to the other idea that science is too cold and hard to deal with moral questions, there is to my regret some ground for that opinion. It is probably based on the behavior of certain scientists who, having made, as far as they have gone, no serious misjudgments, have not been enlightened by the baptism of acknowledged error, and who are therefore harshly overconfident of the correctness of their conclusions. They introduce their would-be rigorous methods of thought into daily intercourse with their neighbors, and are logical when they ought to be genial, argumentative when they ought to be sympathetic; in short, they are very tiresome fellows, and they do science a disservice. No wonder that a gentle-minded person would hesitate to trust scientists of that sort with decisions on delicate problems of right and wrong! But on the other hand, even the best of science is judged cold and hard with little reason by certain sentimental and emotional persons who, reclining on soft couches of prejudice and downy pillows of preference, are intellectually too indolent to face the problems of life fairly and squarely; too unreasonable to subject their opinions to candid scrutiny; too undisciplined to change their beliefs even in the light of compelling evidence. They know nothing of the calm and clear spirit of free inquiry; they are unwilling to follow free

inquiry to an unwelcome conclusion; for example, they reject the philosophy of evolution because, as they fastidiously phrase it, they do not like the idea of being descended from monkeys. I do not believe we need take their condemnation of science as being cold and hard any more seriously than their rejection of evolution because they do not like it.

No, the natural history of goodness lies manifestly within the field of scientific inquiry, and true scientific inquiry will not be either cold or hard in reaching conclusions about it. Scientific inquiry will, indeed, remove from the minds of intelligent thinkers at least, a very cold and hard religious view of ancient origin to the effect that punishment, either in this world or in hell, is the best means of suppressing evil; and will also remove, I hope, the equally primitive view that rewards, either in this world or in heaven, are the best means of promoting good. And let me note in passing that the dependence of the Israelites largely upon punishment, and frequently upon very harsh punishment, as a means of improving human behavior is another of the many evidences for the human origin of their code of morals. It is natural enough that crude views regarding the wish for reward and the fear of punishment should have been characteristic of ignorant ancient peoples, just as they are still characteristic of unintelligent modern peoples. But it is clear enough to-day that fear of punishment is often unsuccessful in the prevention of evil, and that expectation of reward, especially of distant reward, is not very successful in the promotion of good. There is great need of finding something better than reward and punishment as a means of improving the world.

Can the scientific study of the natural history of goodness discover something better? It ought at least try to do so; and in the belief that it will do so lies the optimism of science; but it will take a long time to reach results. For as I have already noted the natural history of goodness includes a study of the forces by which good thoughts and actions may be encouraged and strengthened, and bad ones inhibited. How will the study proceed? Undoubtedly by the standard scientific method of observation, invention, deduction including experiment, and verification; in a word, reasonably. The facts to be studied are, of course, plainly enough very unlike the visible and periodic variations of the tides as controlled by the moon and the sun, and very unlike the present distribution of plants and animals as a consequence of the long past, invisible, non-periodic changes of the geographical cycle; but just as certain appropriate means have been found for solving those unlike problems under the four-faculty proceedure of modern science, equally appropriate means will, it must be hoped, be found for the

solution of this human problem. Efforts toward its solution by the current methods of improving personal and public morals as a part of religious training will of course be continued; but I hope they may be supplemented by systematic instruction in ethics as a branch rather of natural history than of philosophy in schools and colleges.

Goodness Taught By the Case Method

In such instruction the nature of the subject should not be set forth so much in impersonal generalizations as by the "case method," the same method which Louis Agassiz so successfully introduced into the study of zoology, which Langdell with equal success applied to the study of law, and which is now increasingly employed in the Harvard Graduate School of Business Administration as the best means of inculcating sound business principles. Indeed, the natural history of goodness lends itself remarkably well to this method of presentation; for its facts may be set forth in collections of concrete examples of various kinds of behavior, concerning which the pupils may make their own judgments and generalizations; and such collections of examples may be graded from elementary to advanced, so as to afford excellent material for individual exercises from early school years onward. But in the meantime, while such instruction is going on, the specialists in this branch of natural science must extend their investigations by carrying their observations over a great number of individuals, and by devising ingenious experiments concerning all sorts of pertinent conditions.

Observation will be difficult because it will have to take account of the endless diversity in the dispositions and capacities of boys and girls, men and women; but it must not be neglected. Experiments will be intricate, for they will operate slowly and will be hard to follow; but they must not be omitted. Both observation and experiment must be directed in particular to determining how far the love of goodness and the hatred of evil can be cultivated and strengthened; and also how far the cultivated love of goodness and the spiritual happiness that comes from good deeds, together with the cultivated hatred of evil and the spiritual distress that comes from bad deeds, may be trusted as guides to conduct, in preference to rewards for good behavior and punishment for evil-doing; and in this investigation due regard must be had to the age and the nature and the environment of the individual. Great results should not be expected, however, until a way is discovered to strengthen the will; and I believe the best way to do that will be to give it opportunity for action in a carefully devised and wisely supervised series of graded exercises, running all through school and college years. We are making a very serious mistake in not introducing

systematic exercises for the development of the will, that is, of self-control, in our educational system.

Objection will probably be urged against the proposition to teach goodness as a branch of natural history. It will be said that the omission of all mention of God is fatal to its acceptance and its success. In my judgment, our relation to the Infinite should be excluded from natural history and assigned to religious instruction, where it should be treated with the utmost reverence; while the natural history of goodness should be taught just as other branches of natural history are taught, entirely apart from any idea of special creation or any miraculous interference with the order of nature. But it should be taught with a gentleness, a delicacy, a sympathy not to be imagined by persons who think of science as cold and hard, and of scientists as chiefly engaged in hammering rocks, dissecting animals and pulling plants to pieces. Those who enter this branch of natural history, either as investigators or as teachers, must strive to conduct themselves with the wisdom of the judge, the true insight of the poet, when need be with the tenderness of a mother, and always with the infinite patience of evolution itself. It is a great field and it deserves the devotion of the best minds.

The Greater Faith of Devout Believers

In order to illustrate the reasonableness of science I have told you something of the tides as a very specific, quantitative, mathematical problem of four-faculty science; and I have sketched the scheme of the geographical cycle as a highly speculative problem, in the qualitative treatment of which the four-faculty procedure has nevertheless been encouragingly successful. Finally I have outlined the natural history of goodness in order to exemplify the broad range of moral questions over which the four-faculty method of scientific inquiry may be hopefully extended. You will, I trust, accept the tides and the geographical cycle as problems of some interest and importance; but I hope you will regard the natural history of goodness as a much more interesting and a much more important subject of scientific study, particularly as an illustration of the reasonableness of science. If you do so, I beg that you will encourage the cultivation of that branch of natural history and favor its introduction, by means of the case method, into our educational system. There will be of course, as already intimated, those who will say that, just as in replacing special creation by evolution, so in replacing the revelation of goodness by its experiential development, we are acting as if we had lost faith, as if we were unbelievers; but for my part I hold that we are thus acting as most sincere, most earnest, most devout believers, and as having the greater faith.

ASTRONOMY IN CANADA[1]

By Dr. OTTO KLOTZ

DIRECTOR OF THE DOMINION OBSERVATORY, OTTAWA

LET me first extend greetings from my native country Canada to our nearest and closest neighbor and friend—you of the United States. Although two flags wave over our countries, there is only one celestial vault to cover us; the same stars smile on you as on us, and we both appeal to them to help solve the riddle of the universe. Our aims and our aspirations are, I think, the same—the uplift of our people, the utilization of all our resources for the common weal, the widest distribution of the amenities of life, but all founded on the eternal gospel of work.

I think we will find that the origin of all national observatories has been to supply a distinct want or need in the affairs of the nation concerned. So it was with the Royal Observatory at Greenwich and so it was with us. You will recall that it was essentially the question of determining longitude at sea that decided Charles II—in spite of the evil reputation he earned for himself—to command the Rev. John Flamsteed "to apply himself with care and diligence to improve the Table of the positions of the Fixed Stars and Moon to find out the much desired Longitude at Sea, for the perfecting the Art of Navigation." And so was founded the Royal Observatory in 1675. No thoughts of abstract science were in the minds of its founders. It was founded for the benefit of the Royal Navy, and that is its first object to the present day, although its field of activity has vastly expanded and comprises many lines of research. Now a few words as to the origin of the Dominion Observatory, the national observatory of Canada.

The original Dominion of Canada as born on the 1st of July, 1867, comprised the four provinces of Nova Scotia, New Brunswick, Lower and Upper Canada, or Quebec and Ontario. In 1871 British Columbia entered the Dominion, and amongst the terms of federation was that Canada was to build a railway to and through the province to the Pacific Ocean, while British Columbia on her part would convey to the Dominion all lands held by the Crown within 20 miles of the contemplated railway. I may say here that there

[1] Subject matter given in an illustrated ex-tempore address before the Academy of Arts and Sciences, Brooklyn, on February 28, 1922.

was some difference of opinion as to what 20 miles meant along a naturally very sinuous railway of over 500 miles through a sea of mountains. There was of course only one correct interpretation, and that was the area covered or swept by a 20 mile long arm attached at right angles to each side of a moving train.

It was decided by the Dominion Government that the lands to be acquired from British Columbia were to be coordinated with those of the northwest, the survey of which was based on astronomic positions. Although the rectangular system of surveys, the division of lands into sections, townships and ranges was copied from the United States, we in so far improved on it that our system is connected and is a unit, extending from the Lake of the Woods to the Pacific, and from the International Boundary of the 49th parallel to the Arctic Ocean, while in the United States the surveys of the individual states, where the rectangular system applies, are quite independent of each other, and hence lack coordination.

May I here, as I have mentioned the 49th parallel, say a word about its survey, as the astronomer played an important part therein.

You know it's so easy for diplomats sitting about a table to decide the fate of countries and their boundaries. With regard to the latter they are often in blissful ignorance of the geography involved or of the people affected. Certainly nothing could look nicer on paper than a parallel of latitude, which has so simple a definition, curving around the earth. Laying it down on the ground, however, is quite another story. The two astronomers engaged in this international work clearly recognized difficulties that might and would arise in observing for latitude and came to an understanding how to deal with the matter.

The understanding—and a very sensible one—was that the observed latitude was to govern, quite apart from the error that may be involved due to the deflection of the plumb line. The observations themselves, about 50 years ago, being practically devoid of error, were made with present-day accuracy.

The line zigzags, responding to the varying attraction or displacements of the zero of the level from normal. The greatest displacements were the ones to the north of 600 feet, due to the attraction of the Cypress Hills; and the other to the south of 800 feet, due to the attraction of the Sweet Grass Hills in Montana close to the boundary. That is, within a distance of less than a hundred miles we had a difference of 1,400 feet in the gravitational effect due to the unequal distribution of matter along the boundary line. This unequal distribution is not always visible as manifested by the hills spoken of; it might be hidden underneath the surface.

To return to the story of the evolution of the Dominion Observatory: The lands of that 20-mile railway belt in British Columbia were to be coordinated with the land system of the northwest immediately east of the Rocky Mountains. Meridians or parallels could not be projected over the mountains, so the railway itself on the eve of completion was made a base line by a special and very accurate survey. To secure its geographical position a number of astronomic stations were established along the line, and to them was joined the special railway survey. Thereby every part of the line became known by its geographical coordinates and hence surveys could be started where required for mines, timber or other purpose, and expressed in sections, townships and ranges. Thus was born astronomy, practical astronomy, in Canada as a function of the government. That little lamp lit in 1885 was tenderly cared for, fostered and developed and its usefulness extended so that 20 years later the government built the Dominion Observatory, the national observatory of Canada, fully equipped for astronomical and astrophysical work as well as for some branches in geophysical work—seismology, terrestrial magnetism and gravity, about each of which I shall make some brief remarks.

To the general public a dome is a *sine quâ non* for an observatory, and yet the fundamental work does not require it. By fundamental work I mean the determination of the accurate position of the sun, the moon, the planets and stars. And that is essentially the work of national observatories for the use of navigators, explorers and astronomers engaged in other lines of work. This work is done with the meridian circle. As its name implies, it is mounted in the meridian and is only movable therein.

The big telescope, the equatorial that can sweep the whole heavens from its dome, is particularly adapted for answering the question of the little rhyme, "Twinkle, twinkle, little star, how I wonder what you are?" That's it, what you are, not where you are (the meridian circle tells that), but what you are, what gases compose your being, have you a companion, what is your temperature, your mass?—there are queries which the equatorial with its attached spectroscope answers.

Our equatorial 15" is at present used exclusively for the determination of radial velocity of stars forming binary systems, by means of the spectroscope. You all know the spectroscope, how the prisms in it break up the light into its constituent rays, each with its particular wave length, to be photographed on a narrow glass plate, together with some standard light. The motion of a star causes its spectrum to be shifted to or from fixed lines or fixed spectrum, depending upon the approach or recession of the star

relative to the earth. The principle is the same as the change in pitch of a locomotive whistling when approaching or receding from a station. A marvel of the spectroscope is the separation of stars into a binary system when the most powerful telescope fails to see but one object, apparently the presence of only one star.

The success that had been attained in the determination of radial velocities led the government to secure a telescope of a far greater light-gathering power and to mount it where the climatic conditions were more favorable than at Ottawa, and particularly where there was an assurance of more clear nights in the year than obtained at the federal capital. Hence was built the Dominion Astrophysical Observatory at Victoria, British Columbia, and the results already achieved there have fully justified the decision. The largest equatorials are invariably reflectors. The one at Mount Wilson, California, has a diameter of 100 inches, while ours, the second largest, has a diameter of 72 inches or 6 feet. Perhaps the most spectacular and beautiful telescopic object in the heavens is the great nebula in Orion. Then there is the great nebula in Andromeda, the brightest one in the sky. Next we see the ring or annular nebula in the constellation of Lyra, which may be seen with even a small telescope. Contemplating these nebulæ, many questions flood the mind to which but very few answers are as yet available. The spectroscope as usual forms our interlocutor and gives us knowledge from the bright lines in their spectrum that they are incandescent gases under low pressure.

Thus by means of the spectroscope revelation after revelation is unfolded, and the fleet-footed messengers traveling at the rate of 186,000 miles a second come to us after their long, long journeys, some hundreds of years, many even thousands of years and bring the welcome news of their distant homes. Let me make a philosophical and perfectly logical statement based on what I have just said, and that is that no astronomer could give you absolute assurance that any stars that you may see to-night are really there, for the news from the nearest one takes over four years to reach us; that is, it would keep on shining for us four years after its extinction.

Another wonder in the heavens is found in the dense globular clusters, and of these the most splendid in the northern sky is the great cluster in Hercules, also known as Messier 13, in which there are more than 50,000 stars.

Mentioning this number may surprise some or most of you; when on a clear moonless winter night you look on the sky, you will be tempted to say, "What myriads of stars stud the celestial vault." That is poetic license. If you could count them, you

would never get as many as 3,000, possibly 2,000 as seen by the naked eye, for there are not over 5,000 stars in the whole sky, northern and southern hemispheres, that can be seen with the unaided eye.

When you board a ship in New York bound for some foreign port, you have the utmost confidence of reaching your destination, but I am sure it never occurs to you that the astronomer has anything to do with it. Yet it is his labors that supply the captain with the data, as found in a nautical almanac, to guide the ship over the watery waste. This astronomic work is undertaken by all national observatories, the determination of fundamental star places. We also engage in this work. The instrument used is called a meridian circle, so named because it is mounted in the meridian, to which its motion is confined. During my own time the work of the astronomer has been greatly assisted by electrical devices. When I began observing—tell it not in Gath—half a century ago, we recorded by eye and ear; that is, with pencil in hand and listening to the beats of a chronometer or clock the transit of a star across the thread of a telescope was recorded. And what do we do to-day? The astronomer at the telescope turns a micrometer screw following the star, and in an adjoining room his observation is not only recorded but printed in hours, minutes and seconds and hundredths of a second on a continuous strip of paper, which can be copied at leisure the following morning. This certainly removes a lot of the drudgery of former days.

The meridian circle is essentially the instrument that furnishes time; although our daily life is regulated by the sun, yet the accurate time is invariably obtained from the stars, which can be far more accurately observed than can such a boiling cauldron as the sun. Has it ever occurred to you that every time you pull out your watch and look at the time you are paying silent tribute to the astronomer? So does every factory whistle that summons to work and every church bell that summons to devotion. The time of all trains in the country is derived from some astronomer—the silent watcher of the skies.

Although most investigational and research work is done amongst the stars, yet the most important celestial body for us, outside of our own earth, is the sun. Every living thing on this earth, vegetable or animal, life in any form, is but converted solar energy, crystallized sunbeams. We are nothing but animated sunbeams, which is a very good reason for giving us sunny dispositions. When we once know more about the behavior of the sun, how the firing is done and the stoking, what material is used for heating, and whether there is a rhythmic periodicity in the ac-

tivities, when we know some of these things we will be able to forecast the conditions upon the earth.

The sun is under daily scrutiny, and is attacked from different angles. We are studying its rotation and problems involved therein, by means of the cœlostat. The earth being a solid, every part of it revolves in the same time; but such is not the case with the sun, as it is a gaseous mass, in consequence of which the equatorial parts revolve faster than parts north or south thereof. The period of rotation of the former is about 26 days, while the polar regions require 4 to 5 days longer. The principle involved in determining the rotation of the sun is the same as that employed in determining the radial velocity of stars, the displacement of the lines in the spectrum caused by the moving body. Hence, if we obtain simultaneously the spectrum of the two limbs or edges of the sun, the one edge through the rotation will be approaching us, while the other one will be receding; the amount of displacement of the lines of the spectrum resulting therefrom will give us a measure of the speed of rotation. Occasionally you see here the Northern Lights, not quite as brilliantly as we have them in Canada, which sails more closely under the Great Bear or Dipper. These Northern Lights or the Aurora Borealis are a manifestation of solar activity, shooting out negatively charged particles into space and those intercepted by the earth, which at its distance from the sun can stop but the minutest fraction of the matter radiated, give the electric glow to the outermost regions of our atmosphere, encountering there hydrogen and helium, giving the whitish greenish tinge to the phenomenon. When the electrically charged particles penetrate deeper and into the region having the presence of nitrogen, the color becomes reddish.

We are engaged too in the study of relative star magnitudes and the variability of their light by photographic means. It seems scarcely necessary to point out that magnitudes determined photographically and by the eye are not necessarily, in fact not generally, the same. The rays of light that are most effective for vision are not the same as those most effective for photographic purposes. For the latter the rays of shorter wave lengths, those towards the blue or violet end of the spectrum are most active in producing a photographic image.

In the foregoing we have given but the briefest outline of the purely astronomic work carried on in the observatory itself, but we engage too in field astronomic work, which was required in the vast expanse of Canada in which up to recent times there were few accurate surveys, and hence the accurate position of points or places was necessary to put Canada properly geographically on the map.

We use a Cooke portable transit of 3 inches clear aperture, and a cement pier is always built for mounting it. The instrument is used both for latitude and longitude work, and such an instrument it was I carried with me around the world some years ago, when I completed the first astronomic girdle of the world, wiring the British Empire together astronomically. Whenever the electric telegraph is available we use it for the determination of longitude. We always connect up our standard sidereal clock at Ottawa with the place where longitude is to be determined even when thousands of miles away, as in British Columbia. But when there is no telegraph line we now resort to wireless. This is a very recent innovation in astronomic work, and we applied it extensively last season in the Mackenzie basin, due to the discovery of oil and the necessity of surveys, which had to be based on astronomic coordinates. Let me but indicate the principle involved in this wireless longitude work. The wireless expert with his outfit by chronometer records the arrival of wireless time signals from anywhere; in the above case he recorded those from Balboa, San Diego, Annapolis, San Francisco, Honolulu and Cavite in the Philippines. At Ottawa with our wireless outfit we record the same or at least some of the stations. The astronomer who is with the wireless expert furnishes him with the accurate local time when the signals were received. Comparison later on with Ottawa shows the difference of time between the two places; hence the longitude. It is to be observed that although the signals received are time signals—but most of no high degree of accuracy—we treat them as arbitrary signals, simply as signals nôted accurately at two places. The question of the origin of the signal comes into consideration by a very minute quantity, *i. e.*, the difference in time it takes to reach the Mackenzie and Ottawa, as the velocity of transmission of the wireless or Hertzian waves is 186,000 miles a second, being the same as that of light.

May I relate a little incident of the Mackenzie on our wireless. It is not astronomic, far from it, but rather worldly. On the 2nd of July last (it was on a Saturday) there came flashing over the earth news in which many people, even nations, were interested, and that news was as promptly and as soon received by our expert in the boreal regions of the Mackenzie as it was probably here in New York, so near the source. To couch it in astronomic terms, the news may be stated that in the binary system Mr. Carpentier was the eclipsed variable; period 4 revolutions in 12 minutes.

By the hyperboreans our expert was looked upon as one suffering from moral obliquity, but time later accorded him the appellation of the prophet of the Mackenzie.

Yes, the Dempsey-Carpentier fight was heralded in the Arctic regions about as soon as in Brooklyn.

The Dominion Observatory participated with Paris, Washington and Greenwich last summer in a wireless longitude determination for Australia in connection with the meridian boundary, 129° East, between South Australia and West Australia. The wireless signals were sent from the Lafayette station at Bordeaux and from Annapolis, and we recorded both.

I may mention that there is under consideration an international wireless longitude campaign around the world, by means of which we expect all countries to link up their longitudes with this international net. We expect to attain such accuracy that a repetition, say in 50 or 100 years, will reveal a bodily shifting of crustal masses, such as the continents, a circumstance that is believed to be and to have been in process for ages. This means that, for instance, America is moving away from Europe. In this international work Canada expects to cooperate, and she is already taking part in the International Astronomical Union which meets in Rome next May, and for which the speaker has been chosen delegate to represent Canada.

Beside the above purely astronomic work in which the Dominion Observatory is engaged, other scientific work falls within its sphere, consequent to the evolution of such work in Canada. We shall now make a rapid review of that work, which may properly be designated geophysics—comprising seismology, terrestrial magnetism and gravity.

Seismology, dealing with earthquakes, we may call the newest of the sciences, for it is only within recent years that we have obtained reliable records of earthquakes, so that we can locate them in unknown regions or in the ocean with a fairly high degree of precision. To give this a more definite meaning let me say that if we have a decent earthquake—one that gets a good grip on the earth to give us a clean record—it can be located, no matter how far away, say within 30 miles. And furthermore, we can determine the actual time to within two or three seconds. The actual time of the occurrence of a destructive earthquake in the Imperial Valley, California, was better determined from earthquake records thousands of miles distant than obtained on the spot.

Fortunately for the determination of the distance of an earthquake three different kinds of waves are simultaneously propagated. Two of them travel through the earth, *i. e.*, dip down into the earth, while the third confines itself to the surface, and each has its own velocity. We may compare these waves to three messengers, starting at the same time to spread the news of the earthquake. From many well-known quakes and their records we have

learned the speed of these messengers; two of them have a variable speed—the deeper they delve into the interior, any way to a depth of about a thousand miles, the faster they go. It is obvious, therefore, if we know the difference of time that it takes any of the two messengers to reach us, we know how far they must have traveled to produce that difference of time; hence we know the distance to the earthquake or epicenter, as it is called. To illustrate the principle in another way: An express train and a freight train leave a certain place at the same time, with an average speed of 45 and 30 miles respectively. You note their arrival in New York and find that the freight arrived ten hours later than the express, which will show that each had traveled nine hundred miles, *i. e.*, the starting point was 900 miles from New York. Quite simple. But what isn't always so simple is to read the record, the seismogram, to tell when the second and third meessengers arrived; the first one is generally easy to read because it begins from a state of quiescence of the instrument, but the other two take experience to decipher the hieroglyphs. It's a wonderful story these messengers write on our photographic record; they tell us where they have been, what the nature of the material is through which they passed, its density, its elasticity, a story as fascinating as that of Homer's "Odyssey," but not so easily interpreted. Seismology is the new science that gives and brings us direct evidence of the interior of the earth, and it has definitely shown and proven that the interior of the earth is not and can not be liquid, although at a very high temperature, because through a liquid our second earthquake wave, which has transverse motion, could not be propagated; one can not propagate transverse motion in water, but one can propagate longitudinal motion such as sound waves have, and this is the nature of the first wave to arrive. In a solid both kinds of waves, however, are propagated.

As to the cause of earthquakes: An earthquake is the release of stresses to which the earth is subjected. These stresses are manifold. Some are cumulative like constant denudation, transport of material from the land to the sea; some are seasonal like the polar accumulation of snow, and there are stresses due to the rotation of the earth, temporary loading by atmospheric pressure, to mention but a few of the contributory causes. Their occurrence or adjustment to equilibrium naturally is effected at the parts least able to resist the stress, and these are along fault lines, old sores in the earth's crust that are not thoroughly healed—healed by first intention, as the surgeon would say. We may, therefore, say very broadly: "No fault lines, no earthquakes." Also the newer geological formations where things have not settled

down so permanently are more subject to quakes than the older ones. The prediction of earthquakes is by no means a chimerical proposition, in broad outlines, at least.

Before leaving this interesting subject may I be pardoned for saying the Seismological Tables published by the Dominion Observatory are universally used in America and to some extent elsewhere.

As a by-product of the seismograph we have found that it records the pulsation of the ocean waves, *i. e.*, we in Ottawa record every wave of the Atlantic that impinges on the coast from Cape Hatteras to Newfoundland. The period of these waves varies from about 4 to 8 seconds, and on the seismogram they look like saw-teeth. These pulsations are transmitted through the crust of the earth. We have been able to link up these microseisms, called micros for short, with areas of low barometer on the Atlantic Coast. At Ottawa we are about 500 miles from the nearest sea coast, and it seems incredible that we receive through the earth these pulsations of the ocean. We have built and installed at Chebucto near Halifax an instrument which I christened "undagraph" or wave writer, which counts and records every wave of the broad Atlantic reaching the coast of Nova Scotia there, and that record or undagram we correlate with the corresponding seismogram at Ottawa.

The next subject in geophysics of which the Dominion Observatory has charge is terrestrial magnetism. That means the determination of the three magnetic elements, declination or variation of the compass as known to the public, inclination or dip and the magnetic intensity. Our work extends from the Atlantic to the Pacific and we have occupied some five hundred stations at each of which these magnetic elements have been determined. The variation of the compass is the element most wanted—the surveyor needs it, so does the explorer, the navigator and many others. When the poet writes "as true as the needle to the pole," he is guilty of poetic license of a serious kind. If a sea captain were to accept that statement he would never reach his destination. In our work we find for instance on the east coast of Canada the needle points 35° to the west of true north and on Vancouver Island 25° to the east, that is, a range of 60° over Canada, two-thirds of a right angle. It is very obvious that for those that use a compass it is very essential that its declination from true north be known. Unfortunately this is not a constant quantity, but is subject to an oscillating daily change and a slow secular one, both of which are quantities that we determine and apply.

In order to assure accuracy we standardize our instruments twice annually. The most accurate time is furnished by means of a pendulum clock. But why does the pendulum vibrate, or

pendulate, to coin a necessary verb? "It can't help itself" would scarcely be a scientific reply. It is the attraction of the earth that tends to restore it to its normal suspended position, the line of action of the earth's gravitational force. This force is affected by the rotation of the earth and the combined effect we call gravity.

The earth is not a sphere; hence points on the surface are at varying distances from the center. Again the centrifugal force due to rotation is greater in the equatorial regions than north and south thereof; in short, for every latitude there is a particular force of gravity, so that a pendulum that would swing or vibrate seconds in Ottawa would not do so here in Brooklyn. It would lose time here. You see you haven't got as much pull here (I am not speaking in a political sense) as we have in Ottawa, but you are more apt to fly off the handle, to use a cant expression, because nearer the equator. From the above statements it becomes evident that the pendulum, an invariable pendulum, gives us a means for determining the relative force of gravity on the earth, and thereby the accurate figure of the earth, its ellipticity, its flattening, as well as anomalies in the distribution of matter in the crust of the earth. This line of investigation is carried on too by the Dominion Observatory and we have about fifty stations distributed over Canada. The period of the pendulum, that is, the time of swing, which is about half a second, is determined to the one tenth-millionth of a second of time; let me repeat ten-millionths of a second of time, and this order of accuracy is shown when observations are repeated at the same place and the interagreement is limited to the units of the seventh place of decimals.

We now know the figure, *i. e.*, ellipticity, with a high degree of accuracy so that we can readily compute what the theoretical force of gravity should be for any given latitude; hence observations there will show the divergence or anomaly for that place, which means that there is an anomalous distribution of matter in and about the crust of the earth. When we speak of crust of the earth, we mean a thickness of about seventy-five miles, which brings us to the stratum of equilibrium or compensation.

All mountains practically float in the earth, the ten or twenty thousand feet or more that they tower above sea-level are not supported by the crust it couldn't do it but they float like an iceberg does in the ocean, which displaces as much water as its own mass above and below water.

These gravity observations have disclosed some interesting facts about what is hidden underground, by the amount of gravitational force or pull that the hidden mass or masses exercise. If there are huge deposits of iron ore, for instance, gravity would be increased, while large deposits of oil or gas or salt would have the opposite

effect. The pendulum thus becomes a scientific divining rod. We may well say—a peculiar concatenation—from the stars we bring to earth accurate time, and that time we use to express gravity, and from the latter divine oil. Perhaps it is fairer to state that the positive statement of the pendulum is when there is an excess of gravity, oil can *not* be present, for that always involves a defect of gravity.

But there is a more delicate and more sensitive instrument for measuring differential gravity, and that is the torsion balance, by means of which actual areas can be mapped out underground occupied by oil or gas or salt, which has recently been achieved in Europe, especially in Hungary. I am glad to state that such an apparatus is now being built for the Dominion Observatory, and it will be, I believe, the first in America for that purpose.

I shall refer to one other geophysical investigation in which we were engaged. Sir George Darwin many years ago concluded that the earth was subject to daily physical tides, beside those of the ocean, *i. e.*, that the earth was squeezed, was deformed by the action of the moon, which is the main factor in our ordinary tides.

Darwin tried to measure the minute quantity, but failed on account of disturbing factors on the surface of the earth. Hecker of Potsdam succeeded by having his instrument in a deep shaft beyond the effects of the daily heating of the earth, in obtaining a value, but there was the anomaly, found too by the Russian Orloff, that apparently the earth was more readily squeezed in a north and south direction than in an east and west direction. The question was referred to Professor Love, probably the foremost exponent in questions of elasticity, but no satisfactory solution was obtained. It was believed that possibly the situation of the observing stations with reference to the ocean might play a part by the gravitational effect of the tide or heaped-up waters upon the horizontal pendulum which was the instrument used, and also by this same mass of water bending the ocean floor and producing slight tilting of the instrument. To settle this the International Seismological Society decided to establish several stations widely differing in their positions with reference to oceans. Canada was assigned a station. The war intervened, and we never met again. However, the problem was attacked by Michelson of the University of Chicago and brilliantly carried out on the grounds of the Yerkes Observatory and in quite a different manner, by observing in 500-ft. 6-in. pipes partly filled with water the change of level. For measuring the minute quantities an interferometer was used, that is, the wave lengths of light were the measuring

rod. It was found that the earth responds practically instantaneously to the action of the moon. The earth as a whole has about the rigidity of that of steel. The surface of the earth rises and falls about a foot twice a day, due to lunar and solar attraction. We are sitting on a long "teeter"—6,000 miles long, with a period of a little over twelve hours—unconsciously teetering. It doesn't seem much, yet in it is bound up the constitution of our earth, and of all objects in the universe what concerns man more than the earth?

And now I have done. I have given you a brief outline of "Astronomy in Canada" the title of my address, together with other scientific work carried on by the Dominion Observatory. Euclid's definition of a point is that which has position but no magnitude—with Canada it is about the reverse with much emphasis on magnitude. We are trying to give it position—a prominent place on the map of a progressive world—a place in the sun—and I am sure you good people to the south of us, who have been basking in sunshine these years, will welcome the kindred spirit from the north, where we are trying to advance knowledge and advance the various fields of development in which we are engaged, so that our work may be a credit to Canada and a benefit to mankind.

THE TAR-BABY STORY AT HOME

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I

ABOUT thirty years ago the late Dr. Joseph Jacobs pointed out that the "Wonderful Tar-baby Story" of *Uncle Remus* has a parallel in a tale of the Buddhist Jātaka-book, where the most salient feature of the Negro story, the "Stick-fast motif, occurs.[1] Since then students of folk-tales have discussed that story with an almost undue respect for his enticing theory that it originated in India, passed to Africa in very early, perhaps prehistoric, times, spread over that great continent, and at last came to our shores deep-rooted in the souls of our Negro slaves.

What is more, since Dr. Jacobs first expressed his opinion, additional evidence has become available seeming to support at least the first part of his thesis, namely, that India is the ultimate home of the story, although other parts of his proposition have been variously modified.[2] For example, it has been suggested that the story did not reach Africa until comparatively recent times, say the sixteenth century, when it was taken there by Portuguese sailors. Latest, a well-known American folklorist has found the Tar-baby story in the Cape Verde Islands attached to the "Master Thief" cycle of tales—a cycle first presented to the Occident by Herodotus in his account of the robbery of King Rhampsinitus' treasury. On the basis of this discovery, she has suggested a theory that the Tar-baby was originally a part of the Master Thief tale, that they both came from India to Western Asia and Africa, and proceeded thence to Africa. There the Tar-baby feature was clipped or detached from the larger story and has since maintained an independent existence.[3] The idea is ingenious, but it is too much based on unprovable hypotheses to be convincing.

[1] Pañcāvudha-jātaka (Jātaka 55). Dr. Jacobs' remarks may be found in the following of his books: *The Earliest English Version of the Fables of Bidpai*, Introduction, p. xliv; *The Fables of Æsop* (Caxton's edition), vol. 1, pp. 113 and 186; *Indian Fairy Tales*, story of "The Demon with the Matted Hair."

[2] *E. g.*, see Dähnhardt, *Natursagen* 4, 27ff.

[3] E. C. Parsons in *Folk-Lore*, 30: 227. Her theory is untenable: (1) Herodotus' tale is not necessarily to be derived from an Indian source, for it

But the main question, that of Hindu origin of the Tar-baby, still remains unchallenged, and yet it is one that may well arouse scepticism.

The story has been reported in print oftener from Africa, including the Cape Verde Islands, than elsewhere—twenty-two times according to my own account, which is doubtless not quite complete—and this, too, in spite of the fact that African folk-lore has been less fully explored than that of India. Nor is there any part of Africa where it has not appeared, as far as I know, unless it be Egypt. It has been brought to light ten times among American Negroes, fourteen times among American Indians, seven times in India, and twice in the Philippines.[4]

Of these fifty-five versions fifty-two are "folk-tales" in the strictest sense of the word, that is, they are tales current orally among the illiterate folk, that have been secured by collectors from *viva voce* narration; further, they have been collected within the past sixty years. The other three versions are "literary," being found in professed works of literature, and come from India. The oldest of these three may be earlier than the dawn of the Christian era, for it is included in the *Samyutta Nikāya*, a division of the Southern Buddhist canon containing a number of religious discourses ascribed to the Buddha. The second is that known to Dr. Jacobs, a story of the fifth century Jātaka-book, which is a work portraying the Buddha's experiences in a number of previous existences. The third is a brief parable in a medieval Jain text, also religious, called the Parsistaparvan.

The story generally appears in a fairly well stereotyped form, showing a clever animal, in a few instances a man,[5] engaged in thieving, that escapes all efforts to catch it until the injured party —another animal or man—fashions as a trap an image made of

can be assigned an earlier date than any version of the Master Thief found in India; (2) No version of the Master Thief from India has the Tar-baby attached to it; (3) the Cape Verde Island tale is merely the usual tale contaminated by the Tar-baby idea, or at least the Stick-fast motif.

[4] For a list of references to the Tar-baby see Parsons, *l. c.* But add the following: (1) for Africa: Barker and Sinclair, "West African Folk-Tales," p. 71; Nassau, "Where Animals Talk," p. 23; *Folk-Lore*, 10: 282; 20: 443; 21: 215; (2) for India: (*a*) literary: Samyutta Nikāya, 5: 3, 7; Parisistaparvan, 2: 740; (*b*) oral: *Indian Antiquary*, 20: 29, and 29: 400; Gordon, "Indian Folk Tales" (2d ed.), p. 67. Mrs. Parsons has already noted the other versions from India, namely, that of the Jātaka-book (literary) and Bompas, "Folklore of the Santal Parganas," p. 325 (oral). For the valuable reference from the Samyutta Nikāya I am indebted to Dr. E. W. Burlingame.

[5] The Cape Verde Island stories and the Jātaka, but in the latter case the hero is not a thief (see discussion below).

some sticky substance, such as wax, resin, rubber, tar, or bird-lime, which the thief mistakes for a living being. Often the image is that of a female, thus subtly calculated to play to the sex impulse of the offender, who is always a male.[6] Anxious to become acquainted with this stranger, the thief accosts him (or her), but persistently receiving no reply to his overtures, he strikes the image and sticks fast, caught successively by hands, feet and head. (This is the Stick-fast motif.) There is usually a sequel in which the hero by a clever trick effects his escape. The only versions which depart strikingly from this general pattern are the three literary versions from India.

II

The case for India as the home of the Tar-baby story rests in general upon two arguments. The first was thirty years ago the major premise of nearly all studies in the history of folk-tales; it is that "India is the home of stories." Hence any version of a story that appeared in India was regarded as being truly "at home" there, and further as being the most original version of that tale. We now think differently. We concede that many stories of wide vogue were born in India; but we likewise maintain that many other stories were probably born in Egypt, Sumeria, Mesopotamia, Greece, China or other lands. No country ever had a monopoly in the manufacture of fiction; and only the most stubborn Indophile would argue otherwise. Hence there is no compelling *a priori* ground for looking upon India as the home of the Tar-baby.

The second argument, however, is more cogent. It may be stated thus: "Because the Stick-fast motif, the heart of the Tar-baby story, occurs in India at a time almost two thousand years earlier than it can be proved to have existed elsewhere, we must infer that both the motif and the story originated there." At first sight this reasoning seems unanswerable. But is it? May it not rest largely upon accident? It is true that we have no occurrences of the motif or the story at the beginning of the Christian era among the Negroes, the American Indians or the Filipinos, but for that matter we have no stories at all recorded for these peoples from that early time. The fact is that none of these three peoples

[6] The various forms of the story are classified by Parsons, *l. c.* The version in which the victim is attacked through the sex impulse is the more penetrating psychologically and perhaps the older. The same is perhaps true of the fable of "The Ass in the Lion's Skin." In the Pañcatantra the ass is destroyed because the sight of a she-ass arouses his innate lecherousness and he brays. (To the Hindus the ass is the lecherous animal *par excellence.*) In some other secondary versions, notably the Jātaka, the ass merely feels fear and brays.

has a literature; hence the first reports we have of their fiction come from our own investigators working in modern times. Yet no folklorist would say that these folk were without popular tales two thousand years ago; to do so would involve the rejection of the very corner-stone of folklore studies.

In brief the case for India is based for the most part on a general theory that often fails in specific instances and on a further line of reasoning that is three-fourths *argumentum ex silentio.* What we really need to substantiate a claim for India is these two things: first, proof that the Stick-fast motif and the Tar-baby story have a settled place in Hindu fiction; and, secondly, a definite tracing of their course from India to the other lands where they exist. As it happens, both of these things are lacking.

For neither the story nor the motif has a marked place in Hindu fiction. Look, first, at the three literary versions, remembering to keep them distinct from the modern oral versions. In these three instances we see the motif present, although in every case set in a story vastly unlike that of the Tar-baby. The oldest, that of the *Samyutta Nikāya,* says that there was in the Himalayas a pleasant place where men and monkeys lived. There a hunter, to catch the monkeys, used to smear their paths with a sticky ointment. Those monkeys that were intelligent and not greedy, when they saw the ointment, would avoid it. But when a foolish, greedy monkey saw it, he would grasp it with his hand and then he would be caught. To release his hand, he would grasp the ointment with his other hand; and it too would be caught. Thinking that he would release his hands, he would kick, but his foot would stick fast. So also would his other foot. Then he would bite, and his mouth as well would be held tight. Thus, "caught at five points," he would be taken by the hunter and killed.

This tale is merely a religious parable with the moral attached that he who is ensnared by sin is held ever tighter and tighter until as last he is destroyed. The Jain apologue of the Parisistaparvan is only a poor retelling of this, wherein the moral, however, is more specifically, "Avoid women!" The remoteness of these parables from the Tar-baby story is apparent. In neither of them is the victim a thief; in neither of them is the sticky ointment or pitchblend made into an image or doll; in neither of them is there the escape.

The other literary version, that of the Jātaka-book, is very different from these two, although it also has only the Stick-fast idea in common with the Tar-baby. It tells how the Bodhisatta (the Future Buddha), a prince skilled in the use of five weapons, encounters a notorious monster named "Sticky-hair." The prince

attacks him with fifty arrows, but these all stick harmlessly in the demon's hair; so too his sword, his spear and his club. Enraged, he strikes the monster with his hand, but it, too, is caught tight. He strikes with his other hand, and it likewise is caught. He kicks, his feet stick; and finally he butts with his head, and that as well is held fast. But, even though unable to move and apparently at the demon's mercy, the prince betrays no fear. "A very lion of men is this prince!" thinks Sticky-hair. "How is it," he asks, "that you have no fear of death?" "Why should I?" replies the Bodhisatta. "Every life must have its end. Moreover in my body is a sword of adamant that will chop your inwards into mince-meat; and if you devour me, my death will involve yours also." Convinced, the demon frees him.

This story, which perhaps contains a Buddhist satire on Brahman ascetics and their characteristic matted hair, is also not according to the Tar-baby type. The hero is a man—the only instance where this is the case except in the distinctly secondary version from the Cape Verde Islands, in which the Tar-baby story has become ancillary to the great Master Thief tale. Further, the hero is not a thief; nor does his enemy entrap him with an image, but instead uses his own matted hair—another unique feature. The escape is not by the subtle type of ruse common to the Tar-baby story but by a bald, and rather unconvincing, "bluff."

Clearly these literary tales have but little in common with the Tar-baby story of fifty other versions; they merely exhibit an application of the Stick-fast motif that is after all based upon simple observation of the qualities of pitchblend or matted hair, and arose in India quite outside of the Tar-baby milieu. It may well be that there is no genetic relation between them and the prevailing type.

But the case does not rest here. In addition there are a number of negative considerations that are of weight. If the Tar-baby story originated in India, we should at least expect such a gripping story to maintain a vigorous existence there. But it does not; it seems sterile. For, in the first place, the modern versions in India are not to be connected with those in the ancient literature. In one of them, for example, a farmer, to catch a jackal, buries a wax doll, the size of a baby. The jackal, thinking the grave contains a delicious corpse, digs up the doll and is caught.[7] In another tale the god Mahadeo, seeking vengeance upon a tricky jackal, fashions an old woman of wax on whose arm he places a basket of sweets. These the jackal endeavors to steal and is held fast.[8] The

[7] *Indian Antiquary*, 29: 400.

[8] Gordon, "Indian Folk Tales" (2d ed.), p. 67.

other two modern tales are equally dissimilar from the literary versions and correspondingly close to the general type. Indeed, all four of these modern tales, none of which was reported more than twenty-five years ago, are to be traced back to African sources, having come into the country either directly with the Negroes located chiefly at Bombay or else indirectly with the *Uncle Remus* stories that Occidentals tell to the natives and even translate into the local tongues.[9]

In the second place, there is no evidence that India has given the Tar-baby story or the Stick-fast motif to those of her neighbors whom she has so generously enriched from her literary treasures. Vast numbers of Hindu stories have been taken to Tibet and China in literary form, similarly to Persia and Arabia, but in none of these collections, as far as I know, nor for that matter anywhere in the literatures of these people, does either our story or our motif appear.

The whole crux of the matter on India's side is that neither the story nor the smaller motif seems to grip the Hindu mind; they do not appeal. The religious parables were almost stillborn; and the oral fables themselves are already moribund, being but pale, anemic specimens in comparison with the fullblooded, vigorous tale of the Negroes.

We must, therefore, count India out.

III

Having rejected India, we must now determine, if possible, which of the other lands where the Tar-baby story occurs is its birthplace. The task should not be hard. Obviously, it is not with the American Indians, for there is no means by which they could have sent the story to Africa. On the other hand, it is almost axiomatic that they have received it with many more of their folk-tales from the Negroes, often directly, in other cases through Spaniards, Portuguese, or other Europeans. The Filipinos can be rejected on nearly the same grounds and with the same degree of certitude; while the Portuguese in the Cape Verde Islands seem to have got it from the Negroes. There is left only Africa.

And Africa is eminently suited to fill the needs of the situation. First of all, it is a plausible center for the story's radiation. Slaves brought it thence to this continent; other Negroes, or perhaps the *Uncle Remus* books, have taken it to India in modern times; still other Negroes, or possibly Spanish sailors, have planted it in the

[9] See an illustration reprinted from one such translation facing page 300 in Julia Collier Harris's "The Life and Letters of Joel Chandler Harris"

Philippines. These are the only people among whom it has yet appeared, to the best of my knowledge, but if it should at some time appear among other peoples, I am confident that it will be easy to uncover its tracks back to Africa.

But more important is the fact that the Tar-baby is the story that more than any other holds the Negro's mind, and it holds his mind more than it does the mind of any other people. Three fifths of the "genuine" versions are his. All negroes know it and love it. A friend living near Baltimore tells me that he once had a cat named "Tar-baby." The suggestive power of this name was so great that an old colored servitor of his, merely on seeing the cat walk across the yard, would be thrown into violent fits of laughter. Other friends have told me of Negro servants who were acquainted with the Tar-baby story, and that too not from reading. The story is the common property of the black race. It is for them, as it were, the climax of a great animal epic, the grand theme of their fiction.

Fundamentally there is no reason why the Negro should not be the creator of the tale. He has created others; at least he tells a number of stories that seem unknown to other peoples.[10] Once created the tale was bound to live and wander just as perseveringly, though perhaps not so widely and quickly, as one that arose in India or Babylonia or Egypt; for vitality and travel are prime qualities of folk-tales. Hence it has in time become one of the Negro's few contributions to the general culture of the world.

[10] For example, the story of the two animals that make a hunger wager. The one that can go without food the longer is to secure the prize, which is frequently the hand of some female.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture III—Bees Solitary and Social

To those who are not entomologists the word "bee" naturally signifies the honey-bee, because of all insects it has had the most delightful, if not the longest and most intimate association with our species. Of course, the key to the understanding of this association is man's natural appetite or craving for sweets and the fact that till very recently honey was the only accessible substance containing sugar in a concentrated form. It is not surprising, therefore, that man's interest in the honey-bee goes back to prehistoric times. He was probably for thousands of years, like the bears, a systematic robber of wild bees till, possibly during the neolithic age, he became an apiarist by enticing the bees to live near his dwelling in sections of hollow logs, empty baskets or earthen vessels. Savage tribes keep bees to-day and within their geographic range we know of no people that has not kept them. They figure on the Egyptian monuments as far back as 3500 B. C., and we even know the price of strained honey under some of the Pharaohs. It was very cheap—only about five cents a quart.

The keeping of the honey-bee could not fail to excite the wonder and admiration of primitive peoples. It was at once recognized as a privileged creature, for it lived in societies like those of man, but more harmonious. Its sustained flight, its powerful sting, its intimacy with the flowers and avoidance of all unwholesome things, the attachment of the workers to the queen—regarded throughout antiquity as a king—its singular swarming habits and its astonishing industry in collecting and storing honey and skill in making wax, two unique substances of great value to man, but of mysterious origin, made it a divine being, a prime favorite of the gods, that had somehow survived from the golden age or had voluntarily escaped from the garden of Eden with poor fallen man for the purpose of sweetening his bitter lot. No wonder that the honey-bee came in the course of time to symbolize all the virtues—the perfect monarch and the perfect subject, together constituting the perfect state through the exercise of courage, self-sacrifice,

[1] Lowell Lectures.

affection, industry, thrift, contentment, purity, chastity—every virtue, in fact, except hospitality, and, of course, among ancient peoples bent on maintaining their tribal or national integrity, the fact that bees will not tolerate the society of those from another hive was interpreted as a virtue.

With the passing centuries the bee became the center of innumerable myths and superstitions. It was supposed to have played a rôle in the lives of all the more important Egyptian, Greek and Roman divinities. Among the Latins it even had a divinity of its own, the goddess Mellonia. Medieval Christians seem to have been quite as eager to show their appreciation of the insect. While the housefly had to be satisfied with the patronage of Beelzebub and the ant was given so obscure a patron saint as St. Saturninus, the honey-bee enjoyed the special favor of the Virgin or was even made the "*ancilla domini*," the maid-servant of the Lord. Those who represented the divinity on earth, of course, added the honey-bee to their insignia. It appears on the crown of the Pharaohs as the symbol of Lower Egypt, on the arms of popes and on the imperial robes of the Napoleons. Among the ancients the behavior of bees was supposed to be prophetic and the insect thus naturally became associated with Apollo, the Delphic priestess, the Muses and their protegées, the poets and orators. Honey and wax were early believed to have medicinal and magical properties and were, of course, used for sacrificial purposes. Their ritual value is apparent also in the Christian cult, for honey was formerly given to babies during baptism and the tapers of our churches are supposed to be made of pure bees' wax ("*nulla lumina nisi cerea adhibeantur*").

Among the many myths that have grown up around the honey-bee, that of the "bugonia" may be considered more fully, because it shows how entomology may throw light on questions that have puzzled and distracted the learned for centuries. For nearly three thousand years people believed that the decomposing carcass of an ox or bull can produce a swarm of bees by spontaneous generation. The myth evidently started in Egypt and appears in a distorted form among the Hebrews, among whom, however, it is a dead lion in which Samson finds the honey-comb. Among the Greeks and Romans it becomes more elaborate, and Virgil, in the fourth book of the Georgics, and many other authors give precise directions for the killing and treatment of the ox if the experiment is to be successful. The medieval writers repeat what they read in the classics or invent more fantastic accounts. It was not till the eighteenth century that Réaumur showed that what had been regarded as bees issuing from the decomposed ox carcass must

have been large two-winged flies of the species now known as *Eristalis tenax,* which breed in great numbers in carrion and filth and look very much like worker bees. The history of this myth of the oxen-born bees has been more adequately discussed by a distinguished dipterist, Baron Osten Sacken. He remarks that "the principal factor underlying the whole intellectual phenomenon we are inquiring into is the well-known influence which prevails in all human matters, and this factor is *routine.*" "Thinking is difficult, and acting according to reason is irksome," said Goethe. People see and believe in what they see, and the belief easily becomes a tradition. It may be asked: If those people had that belief, why did they not try to verify it by experiment, the more so as an economical interest seemed to be connected with it? The answer is that they probably did try the experiment, and did obtain *something* that looked like a bee; but that there was a second part of the experiment, which, if they ever tried it, never succeeded, and that was, to make that bee-like something produce honey. If they did not care much about this failure, and did not prosecute the experiment any further, it is probably because, in most cases, they found that it was much easier to procure bees in the ordinary way. That such was really the kind of reasoning which prevailed in those times clearly results from the collation of the passages of ancient authors about the "*Bugonia.*"

It would seem that the strange vitality of the bugonia myth during so many centuries must have been due to some keen emotional factor or religious conviction deeper than the mere inertia of routine thinking to which Osten Sacken refers. Let us work backwards from the golden bees embroidered on the state robes of Napoleon I and supposed to symbolize his official descent from Charlemagne, who is said to have worn them on his coat of arms. It is probable that the fleurs-de-lys, which also figure on his arms and those of the later French kings are really conventionalized bees and not lilies, spear-heads or palm trees with horn or amulets attached, as some archeologists have asserted, and that Charlemagne derived his bees from one of the first kings of the Salian Franks, the father of Clovis, Childeric I, who died A. D. 481. In 1653 the tomb of this monarch was opened at Tournay, in Flanders, and found to contain a number of objects which indicated that he had been initiated into the cult of Mithra, that soldiers' religion which had been so widely diffused by the Romans over Gaul, Britain and Germany during the first centuries of our era and had come so near to supplanting Christianity. Among the objects taken from Childeric's tomb were a golden bull's head and some 300 golden bees, set with precious stones and provided with clasps which held

them to the king's mantle. Now the numerous Mithraic monuments that have been unearthed in many parts of the Roman empire show as their central figure Mithra slaying a bull surrounded by several symbolic animals, one of which is the bee. It is known also that honey was used in the initiation rites of Mithra, who was an oriental sun-god like the Hebrew Samson, the Phoenician Melkart and the Greek Hercules. From the blood of the slain bull, a symbol of the inert earth fertilized by the sun's rays, the animal world was supposed to have arisen by spontaneous generation. The bee would seem, therefore, to be one of the symbols of this renewal of life and to recall the epiphanies of many other sun and vegetation gods among the Greeks and Asiatic peoples, such as Adonis, Attis and Dionysus, or Bacchus, who as Dionysus Briseus, the "squeezer of honey-comb" was by some regarded as the god of apiculture. But the bugonia myth can be traced still further back to the Apis cult of the Egyptians. The bull Apis was believed to be an incarnation of the sun-god Osiris and to represent the renewal of life. His son Horus is another sun-god, and it is interesting to note that one of his symbols is the fleur-de-lys, which signifies resurrection. That this is the true meaning of the bugonia myth is indicated also by the magical directions given by Virgil and others for slaying the ox and caring for his carcass. The animal must be carefully chosen and in the spring, when the sun is in the sign of the bull, clubbed to death or suffocated by having the apertures of his body stuffed with rags—obvious precautions to prevent the ox's vitality from escaping so that it may be conserved for the generation of the swarm of bees. The ancients seem to have had an inkling of the parthenogenesis of the honey-bee, since many of them state that, unlike other animals, it never mates. This belief, too, served to connect the bee with the various sun and vegetation gods, all of whom, including the bull Apis, were born of virgins. Thus it will be seen that the bee became the symbol of the ever-recurring resurrection, or renewal of life in general and hence probably also of the second birth of the initiate into such cults as those of Mithra. Unfortunately there were among the ancients no entomologists to point out to the religious enthusiasts that they had mistaken a common carrion fly for the honey-bee and had therefore chosen a wrong symbol.

I have dwelt on this myth because it is such a good example of the bad observation and worse conjecture that have clouded our knowledge of the honey-bee. Even such pioneer observers as Swammerdam, Réaumur and François Huber in the seventeenth and eighteenth centuries and Dzierzon, Leuckart, von Siebold and von Buttel Reepen in more recent times have had difficulty in

clearing a path through the jungle of superstitions and speculations that have grown up around the insect during the past five thousand years. And to-day many of our scientific treatises contain vestiges of these unbridled fancies. Another obstacle to a clear understanding of the honey-bee is the very abundance of the literature. There must have been libraries devoted to it among the ancients, for even Carthage had her celebrated apiarists. Some notion of the present conditions may be gleaned from Dr. E. F. Phillips' statement that the Bureau of Entomology at Washington has a working bibliography of 20,000 titles on the honey-bee. This does not, of course, include a great number of bellettristic works like Virgil's Georgics, Maeterlinck's "Vie des Abeilles" and Evrard's "Mystère des Abeilles."

Greatest of all the sources of a misunderstanding of the honey-bee is the fact that although it is a very highly specialized and aberrant insect, it has been regarded as a paragon in the light of which the social organizations of all other insects are to be interpreted. Its evolutionary interpretation has therefore encountered the same obstacles as that of man, for the honey-bee bears much the same relation to other bees that man does to the other mammals; and just as man's obstinate anthropocentrism has retarded his understanding of his own history and nature, so the apicentrism of the observers of the honey-bee has tended to distort our knowledge, not only of other social insects but of the honey-bee itself. It is necessary, therefore, to relegate the insect to its proper place at the end of a long series of developments. I shall return to it at the end of the lecture.

As classified by the entomologists, the bees comprise about 10,000 described species and occur in all parts of the world. In Europe alone there are some 2,000 species and our North American forms, when thoroughly known, will probably be found to be even more numerous. Less than 500, or 5 per cent., of the 10,000 species are social and belong to only five genera—Trigona, Melipona, Bombus, Psythirus and Apis—the remainder being solitary forms of many genera, several of which are very large and widely distributed. For more than a century talented entomologists have studied the bees intensively but have been unable to work out any generally acceptable grouping of the various genera. Whether these insects are to be regarded as a superfamily (Apoidea), comprising several families, or as a single family (Apidæ), comprising a number of subfamilies, seems to depend on the individual investigator's more radical or more conservative frame of mind.

The bees, taken as a whole, are properly regarded merely as a group of wasps, which have become strictly vegetarian and feed

exclusively on the pollen and nectar of flowers. They are, in a word, merely flower-wasps—"Blumenwespen," as they are called by some German entomologists. A recent authority, Friese, believes that they are descended directly from at least two different ancestral groups of Sphecoid solitary wasps, one of which includes genera like Passaloecus and leads up to Prosopis and other primitive bees, while the other comprises Tachytes-like forms and leads up to the higher bees. It should be noted that a third ancestral group of Vespoids, allied to the Eumenid wasps, evidently gave rise to the Masarinæ, which are also flower-wasps and in their habits closely resemble the solitary bees.

Their very long and intimate association with the flowers has left its stamp on all the organs and habits of the bees, and botanists believe that a great many flowers have been modified in structure, arrangement, color and perfume in adaptation to the bees and for the purposes of insuring cross-pollination. Limitations of time prevent me from dwelling on the vast and fascinating subject of these relationships, though they belong to that order of interorganismal cooperation which I have called coenobiotic. Nor can I stop to dwell on our great debt to the bees for the pollination of our fruit trees and other economic plants. Something must be said, however, concerning the anthophilous adaptations of the insects themselves. It is evident that only insects with well-developed wings, with large, finely facetted eyes and well-developed antennæ, furnished with extremely delicate tactile and olfactory sense-organs, could have acquired such intimate relations to the flowers. And since the bees not only collect but transport the pollen and nectar we find some very interesting structures developed for these particular functions. Two pairs of mouth parts, the maxillæ and especially the tongue, are peculiarly modified for lapping or sucking up the nectar. In the more primitive bees that visit flowers with exposed nectaries these parts are short and much like those of the wasps, whereas in more specialized species that visit flowers with nectaries concealed in long tubes the tongue is greatly elongated. In some tropical bees the organ may be even longer than the body (Fig. 34). In order to store the nectar while it is being transported to the nest, the crop, or anterior portion of the alimentary tract, is large, bag-like and distensible and its walls are furnished with muscles which enable the bee to regurgitate its content. This is known as honey, because the nectar, during its sojourn in the crop, is mixed with a minute quantity of a ferment, or enzyme, presumably derived from the salivary glands, and undergoes a chemical change, its sucrose, or cane sugar being converted into invert sugars (levulose and dextrose).

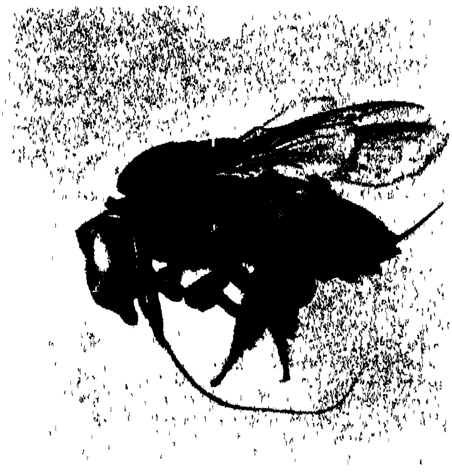


FIG. 34
A long-tongued Neotropical bee (*Eulaema mussitans*) About twice natural size Original

Even more striking are the adaptations for collecting and carrying the pollen. The whole surface of the bee's body is covered with dense, erect hairs, which, unlike those of other insects, are branched, plumose, or feather-like and easily hold the pollen grains till the bee can sweep them together by combing itself with its legs (Fig. 35). Many bees thus bring the pollen together into masses moistened with a little honey and attach them to the outer surfaces of the tibiæ and metatarsi of the hind legs (Figs. 37 and 38). These parts are peculiarly broadened and provided with long hairs to form a special pollen-basket, or corbicula (Fig. 36). In other

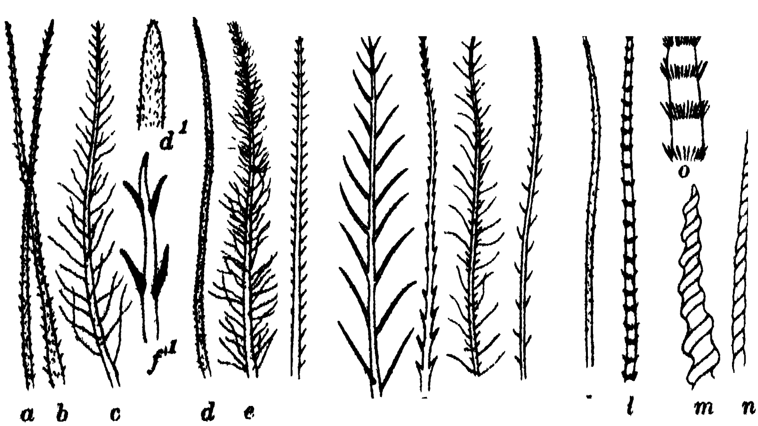


FIG. 35
Hairs of various bees. *a-f*, of bumble-bees; g-j, of *Melissodes* sp.; *k-n*, of *Megachile* sp. After John B. Smith.

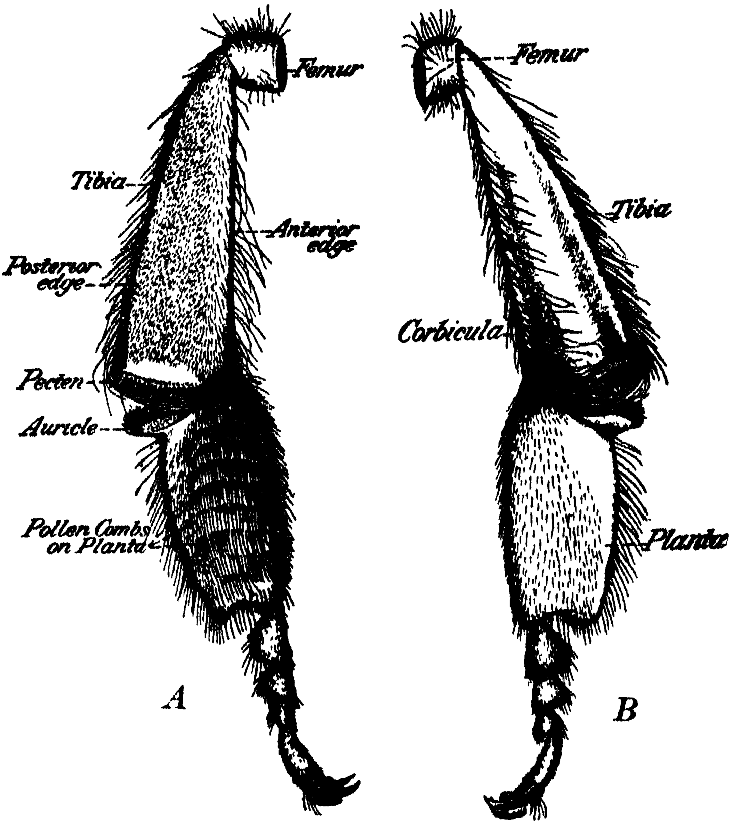


FIG. 36
A Inner surface of the left hind leg of a worker honey-bee, *B* Outer surface of the same. After D. B. Casteel.

bees the pollen is swept to the ventral surface of the abdomen, where there are special hairs for holding it in a compact mass. The bees of the former group are therefore called "podilegous," the latter "gastrilegous." That these various structures, *i. e.*, the general body investment of plumose hairs and the modifications of the hind legs or venter are special adaptations for pollen collection and transportation is proved by certain interesting exceptions. Thus the small bees of the very primitive genus Prosopis look very much like diminutive wasps; they have naked bodies and appendages and their hind legs are not modified. But these bees swallow the pollen as well as the honey and carry both in their crops. Then there is a long series of genera of parasitic bees which lay their eggs in the nests of the industrious species and on this account do not need any collecting or transporting apparatus. Such bees are more or less naked and their tibiæ have returned to the simple structure seen in the wasps. And, of course, since

male bees in general do not have to collect pollen we find that they, too, show considerable reduction in the hind legs as compared with the cospecific females.

There are great differences among the bees in the range of their attachment to the flowers. Some, like the honey-bee and the bumble-bees, visit all sorts of flowers and are therefore called polytropic, whereas others, the so-called oligotropic species, may confine their attentions to the flowers of a very few plants or even to those of a single species. The oligotropic are probably derived from polytropic bees which have found it advantageous to avoid competition with other species and to make their breeding season coincide with the blooming period of a single plant A good example is one of our small black bees, *Halictoides novæ-angliæ* which at least in New England visits only the purple flowers of the pickerel weed, *Pontederia cordata.*

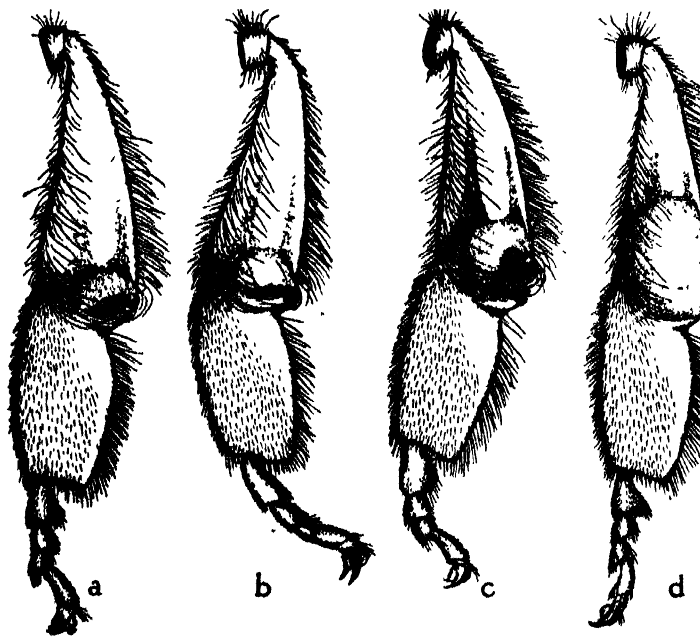


FIG. 37

Outer surfaces of left hind leg of worker bees in successive stages of pollen accumulation. *a,* from a bee just beginning to collect The pollen mass lies at the entrance of the basket. The planta is extended, thus lowering the auricle. *b,* slightly later stage, showing increase in pollen. The planta is flexed, raising the auricle. The hairs extending outward and upward from the lateral edge of the auricle press upon the lower and outer surface of the small pollen mass, retaining and guiding it upward into the basket. *c* and *d,* slightly later stages in the successive processes by which additional pollen enters the basket After D. B. Casteel.

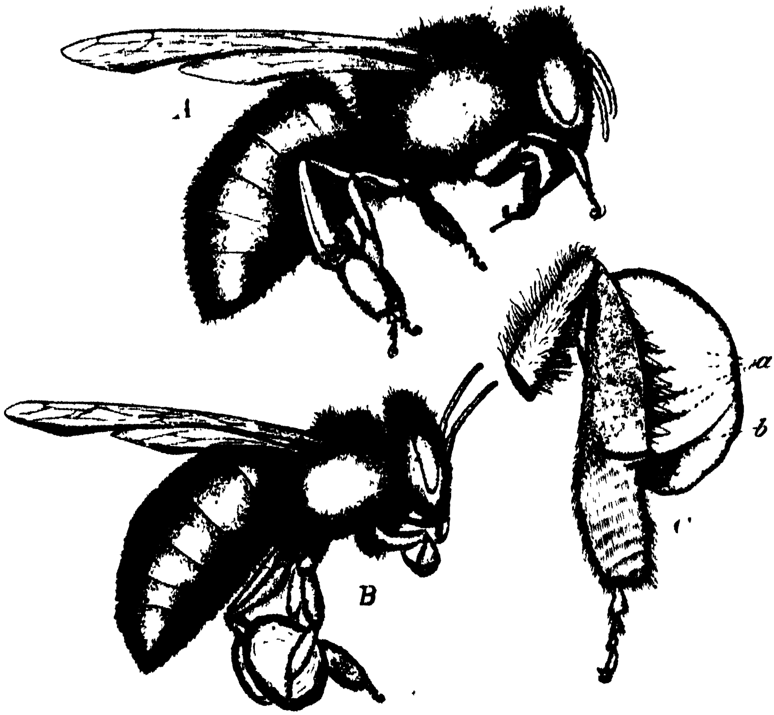
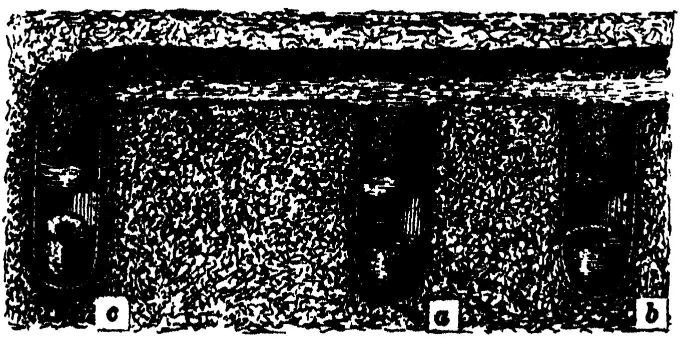


FIG 38

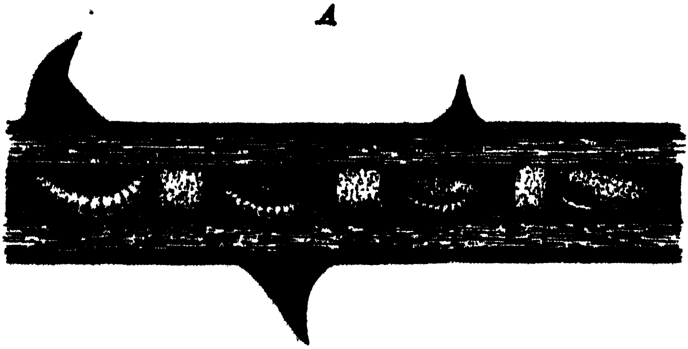
Pollen manipulation of honey-bee. *A*. Flying bee, showing manner of manipulating the pollen with the fore and middle legs. The fore legs are removing the pollen from mouthparts and face, the right middle leg is transferring the pollen on its brush to the pollen combs of the left hind planta. A small amount of pollen has already been placed in the baskets. *B*. Flying bee showing portion of middle legs touching and patting down the pollen masses. *C*. Inner surface of hind leg bearing a complete load of pollen. *a*. Scratches in pollen mass caused by pressure of the long projecting hairs of the basket upon the pollen mass as it has been pushed up from below. *b*. groove in the pollen mass made by the strokes of the auricle as the mass projects outward and backward from the basket. After D B. Casteel.

Turning now to the reproductive behavior which has led to the development of societies we find a most extraordinary parallelism between the group of bees as a whole and that of the wasps as described in my previous lecture. The progress from the solitary condition, shown in more than 95 per cent. of the species, to the conditions in the most highly socialized form, the honey-bee, is, so to speak, a repetition of the various wasp *motifs* set in a different key. Every one of the thousands of species of solitary bees has its own peculiarities of behavior, but the differences are usually so insignificant that the habits as a whole are very monotonous. With the exception of the parasitic bees, which have been secondarily evolved from non-parasitic forms, all the solitary bees make their

nests either in the ground or in the cavities of plants, in crevices of walls, etc., or construct earthen or resin cells (Fig. 39). Some species line their nest cavities with pieces of the leaves or petals of plants, with plant-hairs or particles of wood, or with films of secretion which resemble celluloid or gold-beater's skin. Most of these materials, as will be noticed, are derived from plants. The nest usually consists of several cylindrical or elliptical cells arranged in a linear series or more rarely in a compact cluster, and as soon as a cell has been completed, it is provisioned with a ball or loaf-shaped mass of pollen soaked with honey and called "bee-bread," an egg is laid on its surface and the cell is closed. We have here again the typical mass provisioning of the solitary wasps, very similar to that of the Eumeninæ, except that vegetable instead of animal substances are provided for the young. Nevertheless, the pollen and honey are ideal foods, since the former is rich in



A



B

FIG. 39

Nests of Solitary bees. *A.* Nest of *Colletes succinctus* in the ground. After Valery Mayet. *a*, cell provisioned and supplied with an egg; *b*, cell with young larva; *c*, with older larva. *B.* Nest of a small carpenter bee (*Ceratina curcurbitacea*) in a hollow Rubus stem; showing egg, three larvæ of different stages and bee bread in three of the cells. After Dufour and Perris.

proteids and oils and the latter in sugar and water, and both contain sufficient amounts of various salts for the growth of the larvæ. As in the case of the solitary wasps the mother bee dies before her progeny emerge.

Just as among the solitary wasps, we often find female solitary bees nesting in close association with one another, and in some species (*Halictus longulus, Panurgus, Euglossa, Osmia vulpecula* and *parietina, Eucera longicornia*) the females, though occupying separate nests, nevertheless build a common entrance tunnel. Still there is nothing in these arrangements to indicate that they could lead to the formation of true societies. There are, however, a few cases which might be regarded as sub-social, since the mother bee survives the development of her progeny and shows more interest in their welfare than is implied by the mere mass provisioning of the cells. Two such cases are represented by the European *Halictus quadricinctus,* observed by Verhoeff, and *H. sexcinctus,* observed by Verhoeff, von Buttel Reepen and Friese. The female of the former bee digs a long vertical tunnel in the ground and at its lower end a chamber in which she constructs a number of earthen cells, arranged in the form of a rude comb. These cells of which there may be as many as 16 to 20, are successively provisioned and closed, but the mother is long-lived, guards the nest and may even survive till the young emerge. Hence there is here an actual though apparently very brief contact of the mother with her adult offspring.

Certain peculiarities in the life-history of Halictus may be conceived to tend still further towards social development. According to our present unsatisfactory knowledge of these bees, at least some of the species have two annual generations. The spring generation consists of fecundated females that have over-wintered from the previous fall. These give rise to a summer generation consisting entirely of females. Their eggs develop parthenogenetically, but produce both males and females, forming the fall generation. The males soon die, but the fecundated females go into hibernation. As von Buttel Reepen suggests, a society might be readily established in a form like *H. quadricinctus* if the parthenogenetic generation of females were to remain with their mother and extend the parental nest. This would be essentially what we find in the lower social wasps like Polistes.

A still more interesting case has been found by Dr. Hans Brauns among the bees of the genus Allodape which belong to the gastrilegous division and are closely related to our small carpenter bees of the genus Ceratina, so abundant in hollow stems of the elder and sumach. Dr. Brauns made his observations in

South Africa, where he has been living for many years, and kindly sends me the following unpublished data for use in this lecture:

"The species of Allodape nest in the dry, hollow stems of plants, very rarely in galleries in the soil. In both cases they gnaw out cavities or occupy those already in existence. Plant stems with pithy contents, like those of Rubus, Liliaceæ, Aloe, Amaryllidaceæ, Asparagus, Acacia thorns, etc., are preferred. Three different groups of species may be distinguished according to the method employed in provisioning the young. These three groups may also prove to be useful as morphological sections of the genus, since the majority of Allodape species, especially the smaller ones, are very difficult to distinguish in the female sex. The males yield better characters, though there are few plastic characters in the genus. Most of the descriptions drawn from single captured specimens have little value. Fanatical describers, like some of your countrymen, merely make the work of the monographer more difficult or more unattractive or even well nigh impossible in a genus which is almost as monotonous as Halictus. The three different methods of provisioning which I have been able to establish are the following:

"(1) The most primitive species, observed only on a few occasions. The mother bee collects in the nest tube as much beebread in single loaves or packets as the larvæ will require up to the time of pupation, precisely as in other solitary bees, *e. g.*, as in Ceratina, the form most closely related to Allodape. The single food-packets are arranged one above the other in the hollow stem and each is provided with an egg. The larva holds itself to the food-packet by means of peculiar, long, segmental appendages, which I have called provisionally "pseudopodia," and consumes its single packet till it is time for pupation. The size of the packet corresponds to the size of the particular species, much as in Ceratina, and each packet nourishes only a single larva. The latter holds its appendages spread out like those of a spider and is closely attached to the packet like the larvæ of such solitary bees as Ceratina. So far there is no departure from the conditions in the solitary Apidæ. There is, however, one fundamental difference: Whereas Ceratina after provisioning and oviposition closes off each cell with a partition of gnawed plant materials and therefore makes a series of individual cells, Allodape *constructs absolutely no partitions.* The food-packets, each large enough for a *single larva* and each furnished with a *single egg,* though arranged in a linear series one behind the other in the nest tube, as in Ceratina, Osmia, etc., lie freely one on top of the other and are not separated by partitions of the materials above mentioned. The

lowermost packet is the oldest and is therefore usually found to bear a larva while each of the upper packets bears an egg. This difference, as you will admit, must be regarded as of fundamental importance. In these more primitive species the mother does not come into contact with the larva since the latter has been provided *once for all* with sufficient food to last it till it pupates, precisely as in the solitary bees and wasps. The pseudopodia can not therefore have the function of exudate organs but merely serve to attach the larva mechanically to the food-packet. This transition from isolated cells to a simple unseparated series of packets is, of course, very interesting and significant.

"(2) Rather common small and medium-sized species. The mother bee glues a number of eggs, each by one pole and in a *half spiral row*, determined by the curvature of the tubular cavity, to the wall of the nest, usually near the middle, *i. e.*, a little above or a little below. One common species I have also seen occupying tubular cavities in the earth with a similar arrangement of the eggs. The hatching larvæ hold fast to the walls of the tube by means of their pseudopodia and *are all at the same level with their heads directed towards the entrance to the cavity.* From time to time the mother brings in a small lump of bee-bread and deposits it in the midst of the hungry heads. The larvæ therefore all eat *simultaneously of the same mass of bee-bread.* During their last moult the mature larvæ lose the pseudopodia and become pupæ, which come to lie one behind the other in the tubular nest cavity. In these species, therefore, the mother remains in continuous contact with the larvæ.

"(3) The majority of species, from those of small to those of the largest size. The mother bee lays her eggs singly and loosely on the bottom of the nest tube. In proportion to the size of the bee the eggs are very, one might say abnormally, large and seem to be laid at longer intervals. The mother bee feeds the individual larva, which *clasps the particle of bee-bread* with its two large pseudopodia so that it *has the food all to itself.* When a nest that has been occupied for some time by a mother bee, is examined, one or several larvæ, each with its own pellet of bee-bread, are found in the position I have described. Later the daughters help their mother in provisioning the larvæ. When the colony has become populous the cavity of the tube is found to be stuffed with larvæ and pupæ in all stages. The latest egg, however, almost always lies on the floor of the tube. And since the mother bees must always go to the bottom to feed the youngest larvæ, the contents of the tube are often intermingled, though the larger larvæ and the pupæ are mostly nearer the opening and therefore upper-

most. In these species, also, the larvæ lose the pseudopodia during the last moult."

Brauns's observation on Allodape are of great interest and importance because they reveal within the limits of a single genus a series of stages beginning with a mass-provisioning of the young, like that of the solitary bees and wasps, and ending with a stage of progressive provisioning. And not only has the latter led to an acquaintance of the mother with her offspring but in the third group of species described by Brauns to an affiliation of the offspring with the mother to form a cooperative family or society. It would seem that this condition must have had its inception, as Brauns suggests, in so simple a matter as the omission of the series of partitions which all other solitary bees construct between their provisioned cells. The final stage in which the individual larvæ are fed from day to day by the mother and her daughters with small pellets of food is not essentially different from what we shall find in the bumble-bees and certain ants.

Yet these rudimentary societies of certain species of Halictus and Allodape must not be regarded as the actual precursors or sources of the conditions which we observe in the three groups of social bees, namely, the Bombinæ, or bumble-bees, the Meliponinæ, or stingless bees, and the Apinæ, or honey-bees. Though these all belong to the podilegous division, no one has been able to point out their putative ancestors among existing solitary bees, and it is evident that we can neither derive them from one another nor from any single known extinct genus. Each possesses its own striking peculiarities and each is an independent branch from the ancestral stem now vaguely represented by the solitary bees. The bumble-bees are the most primitive, the honey-bees the most specialized, while the stingless bees exhibit a combination of primitive and specialized characters different from those of either of the other subfamilies. But just as all the social wasps differ from the solitary wasps in employing a peculiar nest material—paper—so the three groups of social bees differ from the solitary bees in using another peculiar nest material—wax. This material is, however, a true secretion, which arises in the form of small flakes from simple glands situated between the abdominal segments of the insects (Fig. 40). The three groups of social bees also agree in the structure of the hind tibia, the outer surface of which is not only broadened as in solitary forms but smooth and shining with recurved bristles along the edges (Fig 36). This is called the corbula and among solitary bees is known to occur only in Euglossa.

The bumble-bees represent a stage of societal development of the greatest interest to the evolutionist. Of these large insects

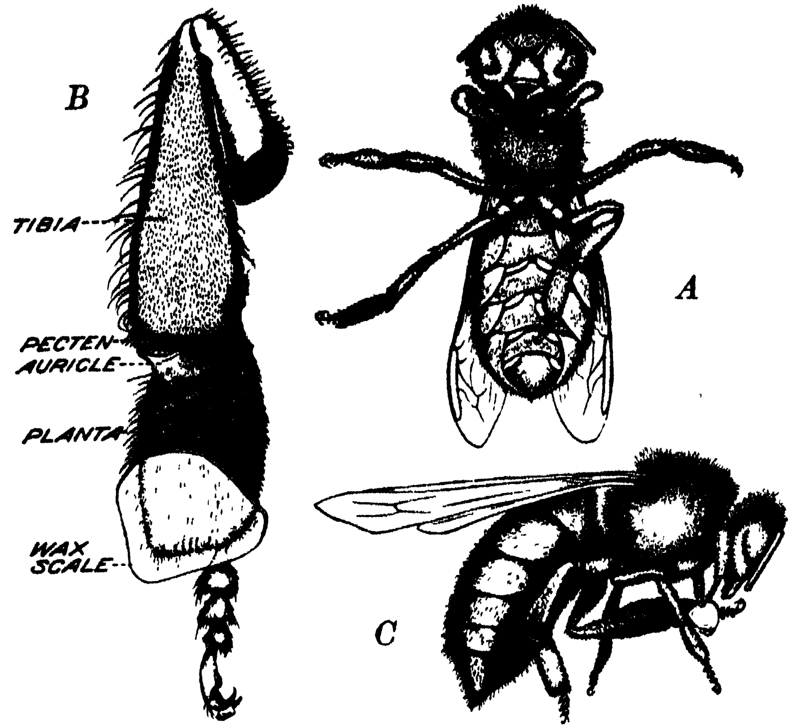


FIG. 40

A. Ventral view of worker honey-bee in the act of removing a wax-scale. *B*. Inner surface of left hind leg, showing the position of a wax-scale immediately after it has been removed from the wax pocket. The scale has been pierced by seven of the spines of the pollen combs of the first tarsal segment of the planta. *C*. Side view of a worker bee showing position of wax-scale just before it is grasped by the fore legs and mandibles. The scale is still adhering to the spines of the pollen combs. The bee is supported upon the two middle legs and a hind leg as in *A*. After D. B. Casteel.

about 200 species are known, mostly confined to Eurasia and North America. They prefer rather cool climates and several species occur in the arctic regions or at high elevations. Their habits have been carefully studied by several European entomologists, notably by Hoffer, Wagner, Lie-Petersen and Sladen, and are beginning to attract students in this country. We know very little about the species of Central and South America and the East Indies.

In temperate regions bumble-bee colonies are annual developments, like those of our northern species of Vespa and Polistes. The large fecundated female or queen overwinters precisely like the females of the solitary wasps and starts her colony in the spring. She chooses some small cavity in the ground or in a log, preferably an abandoned mouse-nest, and after lining it with pieces of grass or moss or rearranging the pieces already present, proceeds to the

important business of establishing her brood. The various stages in this behavior have been carefully observed by Sladen: "In the center of the floor of this cavity she forms a small lump of pollen-paste, consisting of pellets made of pollen moistened with honey that she has collected on the shanks (tibiæ) of her hind legs (Fig. 41*a*). These she moulds with her jaws into a compact mass, fas-

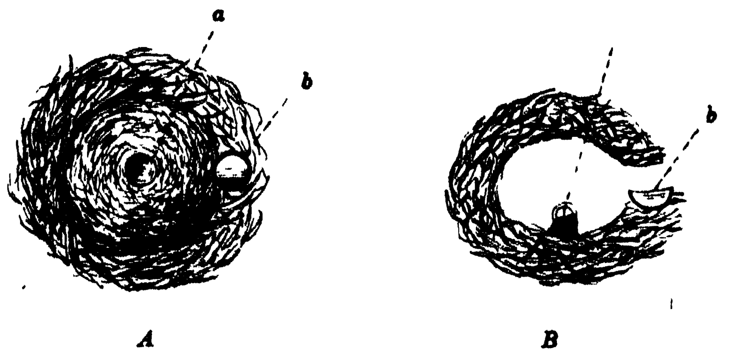


FIG. 41
Incipient nest of bumble-bee *A* Pollen and first eggs *B* Honey pot. After F W L Sladen

tening it to the floor. Upon the top of this lump she builds with her jaws a circular wall of wax, and in the little cell so formed she lays her first batch of eggs (Fig. 42*Ba*), sealing it over with wax by closing in the top of the wall with her jaws as soon as the eggs have been laid. The whole structure is about the size of a pea. . . . The queen now sits on her eggs day and night to keep them warm, only leaving them to collect food when necessary. In order to maintain animation and heat through the night and in bad weather when food can not be obtained, it is necessary for her to lay in a store of honey. She therefore sets to work to construct a large waxen pot to hold the honey (Fig. 41*b*, 43, 44). This pot is built in the entrance passage of the nest, just before it opens into the cavity containing the pollen and eggs, and is consequently detached from it. The completed honey pot is large and approximately globular, and is capable of holding nearly a thimbleful of honey."

Up to this point the behavior of the queen is much like that of the solitary bee which makes and closes her cell after providing it with provisions and an egg, but a significant change now supervenes. The eggs hatch after about four days and the further events are described by Sladen as follows: "The larvæ devour the pollen which forms their bed, and also fresh pollen which is added and plastered onto the lump by the queen. The queen also feeds them with a liquid mixture of honey and pollen, which she prepares by

swallowing some honey and then returning it to her mouth to be mixed with pollen, which she nibbles from the lump and chews in her mandibles, the mixture being swallowed and churned in the honey-sac. To feed the larvæ the queen makes a small hole with her mandibles in the skin of wax that covers them, and injects through her mouth a little of the mixture among the larvæ which devour it greedily. Her abdomen contracts suddenly as she injects the food, and as soon as she has given it she rapidly closes up the hole with the mandibles. While the larvæ remain small they are fed collectively, but when they grow large each one receives a separate injection.''

Here we have a beautiful transition from mass to progressive provisioning. Sladen then describes the further development of the brood: ''As the larvæ grow the queen adds wax to their covering, so that they remain hidden (Fig. 42 *BEb*). When they are about five days old the lump containing them, which has hitherto been expanding slowly, begins to enlarge rapidly, and swellings, indicating the position of each larva, begin to appear in it. Two days later, that is, on the eleventh day after the eggs were laid, the larvæ are full-grown, and each one then spins around itself an oval cocoon, which is thin and papery but tough (Fig. 42 *Cc*). The queen now clears away most of the brown wax covering, revealing the cocoons, which are pale yellow. These first cocoons number from seven to sixteen, according to the species and the prolificness of the queen. They are not piled one on another, but stand side by side, and they adhere to one another very closely,

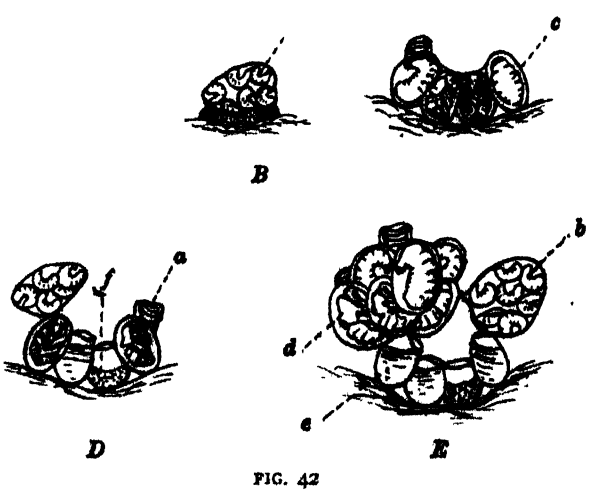


FIG. 42

A to *E*. Diagrams of successive stages in the development of the bumble-bee's brood. *a*, eggs; *b*, young larvæ; *c*, full grown larva; *d*, pupa; *e*, old cocoon used as a honey pot; *f*, old cocoon used as a pollen pot. After F. W. L. Sladen.

FIG. 43
Incipient nest of *Bombus terrestris*, showing honey-pot and mass of wax enclosing young brood and grooved for the accommodation of the body of the queen while incubating. After F W L Sladen

FIG. 44
Same as Fig. 43, showing the queen *Bombus terrestris* lying in the groove and incubating the young brood. After F. W. L. Sladen.

so that they seem welded into a compact mass. They do not, however, form a flat-topped cluster, but the cocoons at the sides are higher than those in the middle, so that a groove is formed; this groove is curved downwards at its ends (Fig. 43), and in it the queen sits, pressing her body close to the cocoons and stretching her abdomen to about double its usual length so that it will cover as many cocoons as possible, at the same time her outstretched legs clasp the raised cocoons at the sides (Fig. 44). In this attitude she now spends most of her time, sometimes remaining for half-an-hour or more almost motionless save for the rhythmic expansion and contraction of her enormously distended abdomen, for nothing is now needed but continual warmth to bring out her first brood of workers. In every nest that I have examined the direction of the groove is from the entrance or honey-pot to the back of the nest, never from side to side. By means of this arrangement the queen, sitting in her groove facing the honey-pot—this seems to be her favorite position, though sometimes she reverses it—is able to sip her honey without turning her body, and at the same time she is in an excellent position for guarding the entrance from intruders.''

The eggs laid by the queen during the early part of the summer are fertilized and therefore produce females, but the larvæ, owing to the peculiar way they are reared, secure unequal quantities of nutriment and therefore vary considerably in size, though

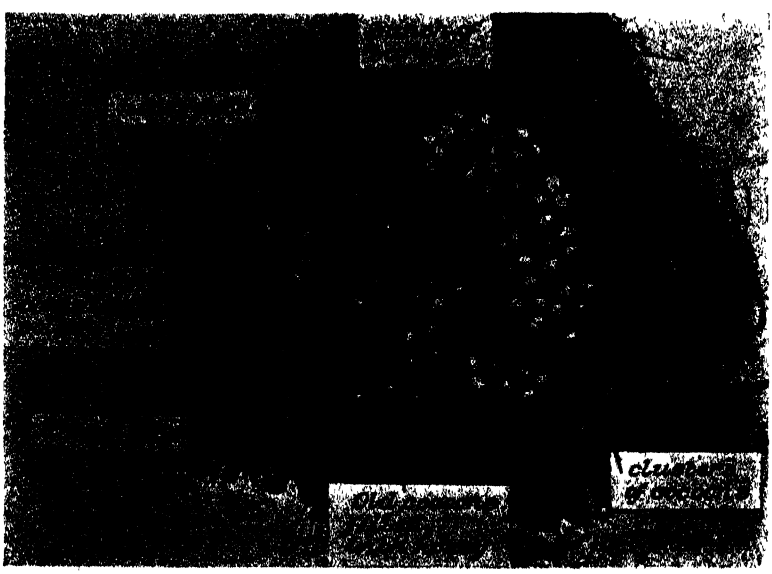


FIG. 45
Comb of *Bombus lapidarius*, showing clusters of worker cocoons, masses of enclosed larvæ, half-full honey-pots and pollen pot. After F. W. L. Sladen.

they are all smaller than their mother. Individuals scarcely larger than house-flies are sometimes produced, especially in very young colonies. All of these individuals have been called workers, although they have essentially the same structure as the queen. They are assisted in emerging from their cocoons by their mother or sisters and forthwith take up the work of collecting pollen and nectar and of enlarging the colony. The queen now remains in the nest and devotes herself to laying eggs, while the nest is protected, new cells are built and the additional broods of larvæ are fed by the workers. They also construct honey-pots and special receptacles for pollen or store these substances in cocoons from which workers have emerged (Fig. 45). Later eggs are also laid by the workers but being unfertilized develop into males. As the colony grows and becomes more prosperous, some of the larvæ derived from fertilized eggs laid by the queen are abundantly fed and develop into queens. Like the queens of the social wasps, these do not emerge from their cocoons till the late summer, and like the queen wasps, they disperse, after mating with the males, and alone of all the colony survive the winter to start new colonies the following spring. In South America, where, according to von Ihering, bumble-bee colonies are perennial, new nests are formed by swarming as among the social wasps of the same region. Bumble-bee colonies are, as a rule, not very populous, 500 individuals constituting an unusually large society. In many cases there are scarcely more than 100 to 200.

I have called attention to the fact that the workers are precisely like the queens, or fertile females, except that they have been more or less inadequately fed during their larval stages and are therefore smaller. They are the result of a high reproductive activity on the part of the queen under unfavorable trophic conditions that do not permit the offspring to attain their full stature. In certain species that live permanently under even more unfavorable conditions, like those in the arctic regions, the worker caste is completely or almost completely suppressed. During 20 years of residence in Tromsö, Norway, Sparre Schneider failed to find a single worker of *Bombus kirbyellus*, and those of *B. hyperboreus* were extremely rare. Probably the queens of these species are able to rear only a few offspring and these are all or nearly all males and queens, though, during the short arctic summer, at least in Finland and Lapland, the mother insects work late into the nights. But the worker caste may also disappear as a result of the opposite conditions, that is, an abundance of food. We found this to be the case with the workerless parasitic wasps, *Vespa arctica* and *austriaca*. In north temperate regions the genus Bombus has given rise to a

number of parasitic species, which have been included in a separate genus, Psithyrus. These bees are very much like Bombus, in the nests of which they live, but just as in the two species of Vespa and for the same reasons, their worker caste has been suppressed.

The foregoing account shows that the bumble-bees are very primitive and represent an interesting transition from the solitary to the social forms, since the queen while establishing her colony behaves at first like a solitary bee but later gradually passes over to a stage of progressive provisioning and affiliation of her offspring and thus forms a true society. The cells are also essentially like those of solitary bees, except that they are made of wax, but even in the secretion of the wax the bumble-bees represent the primitive conditions, as compared with the stingless bees and honey-bees, since the substance is exuded between both the dorsal and ventral segments of the abdomen.

THE POLYNESIANS: CAUCASIANS OF THE PACIFIC

By CLIFFORD E. GATES
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IN the oceanic islands of the Pacific three different peoples occur, who have been called Melanesians, Micronesians and Polynesians. These form very distinct divisions. The Melanesians are physically negroid, nearly black with crisp, curly hair, flat noses and thick lips. Although nothing is known of their origin, it is supposed that they came from Africa and were the earliest occupants of the oceanic world. They now occupy the western portion of the Pacific islands south of the equator including Fiji, the New Hebrides, the Solomon group and the Bismarck Archipelago.

The Micronesians are of Malay stock much modified by Melanesian, Micronesian and even Chinese and Japanese crossings. They are short, often stunted in form, and have a dark brown complexion. They inhabit the western portion of the Pacific islands north of the equator, including the Marshall Islands, the Gilbert Islands, the Caroline Islands and Guam.

The Polynesians represent a branch of the Caucasian race who migrated in a remote period, possibly in the Neolithic age, from the Asiatic mainland. They have a distinct European cast of feature, have a light brown or olive complexion, and are the physical superiors even of Europeans. They inhabit all the eastern group of islands both north and south of the equator, including the Hawaiian, Marquesan, Society, Cook, Tonga and Samoan Islands.

The Micronesians, few in number and inhabiting a relatively small area of Oceanica, have been of little interest to other peoples; the Melanesians, black and savage, with a history of horror after horror, have been repellent to explorers and remain in a darkness comparable to the darkness of central Africa. But the Polynesians have cast a charm over the civilized world. They are perhaps the handsomest people extant. The men average six feet in height, are strongly muscled, free from fat, swift in action, graceful in repose; the women are often of rare beauty, with regular features and wondrous large, dark eyes. In character they are exceedingly merry, gentle, courteous and hospitable. Unless mistreated or under some misapprehension they have been almost universally friendly

to the white man; the stranger coming to their shores and passing through their villages ever and anon receives the greeting "aloha," and his departure is often the cause of sadness or weeping on the part of the islanders who may have known him at most but a few days. When Robert Louis Stevenson was about to leave the Marquesas—islands owned by France—Stanislao Moanitini, chief of Akaui, sadly addressed him with these words: "Ah vous devriez rester ici, mon cher ami. Vous êtes les gens qu'il faut pour les Kanaques; vous êtes doux, vous et votre famille; vous seriez obéis dans toutes les îles."

Nowhere does any people possess a deeper passion for color; wreaths or "leis" of flowers have always been a part of their everyday attire. Their personal cleanliness is remarkable. For them no day would be complete without a bath in one of their beautiful streams or lakes followed by an anointing of the entire body with a fragrant oil.

With these people cultured Europeans have not hesitated to form marriages, to live among them, sensitive natures have counted the world well lost, and about them has grown up a romance of story and song that has caught the interest of the civilized world. There is a saying that he who has seen Tahiti will never wish to leave it.

Their history prior to the discovery of their islands by Europeans has been learned partly through study of their characteristics, partly through study of their language, but principally through their traditions and legends. Though many examples of their rude hieroglyphics or picture symbols have been found, little has been learned from this source. The appearance and characteristics of the people point at once to a Caucasian lineage. The roots of their language point to the same conclusion. This being so, they could have come only from Asia. All their legends point to the west as the cradle of the race, and their dead are supposed to go to their future life west—naturally back to the *home* of the race. But supposing they did come from Asia, how did they ever reach Samoa and Tahiti and Hawaii? Hawaii is over 4,000 miles from Asia and only 2,000 from San Francisco. How could these people traverse two thirds of the Pacific in their canoes? Doubtless they came from island to island through the Malay Archipelago until they reached Samoa, but from there they had 2,000 miles of open ocean to traverse to reach Hawaii. How was it possible to accomplish this sail from the west when the prevailing winds and currents were from the northeast? The answer to this question lies in the character of the people. There is evidence that in the past they were the most daring and skilled navigators the world has

ever known. They built two-decked canoes of plank large enough to carry big stores of food and water and even livestock. They possessed a knowledge of the stars and steered their course by them. That they must have come this way is further evidenced by the fact that an intelligent Polynesian of Hawaii can understand almost everything that a Samoan says even though the islands lie so far apart, and, except for the several waves of colonization, have had no intercourse with each other prior to the arrival of the European. Nearly all the ethnologists are agreed upon this theory of the origin of the race. At the present time further investigations are being made by the Bishop Museum and Yale University. Their work is only half completed, but already they have collected a vast amount of information which it is believed will still further corroborate the accepted theory.

Arrived at the islands the Polynesians found conditions admirably suited to their needs. The soil, usually being of volcanic origin, was fertile and covered with a rich vegetation, including the taro, the bread-fruit, the sweet potato, the yam and the banana. The waters about the islands abound in fish, and though no edible animals appear to have been indigenous, the early settlers brought with them pigs which flourished in both a wild and domestic state and have always been highly regarded as a food by the natives.

For many centuries they led a savage but contented existence here, completely shut off from the rest of the world. Happy would they have been if they could have remained in this seclusion! Early Spanish navigators touched at some of the smaller islands and by the eighteenth century all of the main groups were known. The Hawaiian Islands were the last to be discovered, being unknown until an English navigator, Captain James Cook, landed there in 1778.

At the time of discovery the different groups of islands were in various stages of advancement, the Samoans being the most civilized and the Marquesans the most savage. All of them were living in a feudal state, similar to that which prevailed in Europe in medieval times. The chiefs owned all the land and parcelled it out among their followers, who however were not bound to the land but if dissatisfied could transfer their allegiance to some other chieftain. For many years there had been waging almost continual internecine wars which must have limited the population even before discovery.

Since the coming of the European many changes have taken place in government, mode of living and religion. The islands are no longer independent. The Marquesan and Society Islands belong to France; the Cook and Tonga Islands belong to Great

Britain; the Hawaiian Islands and part of Samoa belong to the United States. The people have largely abandoned their ancient manner of living and adopted that of the European. One of their most peculiar systems was that of the tabu. The tabu was a prohibition of certain articles or certain acts and was religious in character. Anyone who violated a tabu was supposed to be visited by a certain malady and, unless the proper remedial measures were taken, in three days' time to die. Anyone could tabu anything that belonged to him, but there were a great many tabus of universal application. The following are examples: men and women were compelled to eat in separate houses, and women could not cook over a fire built by a man. Women were not allowed to eat certain food such as bananas, cocoanuts and pork. Women could not enter any canoe, but if they desired to cross any river or lake or reach a ship had to swim. A commoner was prohibited from crossing the shadow of a chief. At certain tabu periods no sound could be heard, no fire could be lighted, even the dogs were muzzled and fowls tied up. For various reasons the system is now overthrown.

The simple dress of the people, which consisted for the men of a loin cloth, for the women of a short girdle of leaves, has been changed for the more elaborate dress of the European. The native houses made of bamboo poles and thatch have given place to houses of wood. Even the occupations have changed. Formerly the native did little work aside from picking and cooking his food, spearing fish and making his simple dress and implements. Now many products are raised for export, the cultivation of sugar especially having become the main industry of most of the islands. The native religion, with its many gods, its prayers and its songs, has yielded to Christianity, the islanders accepting the new religion en masse. Doubtless the acceptance in many cases has been largely a matter of form, for the inhabitants in times of trouble still secretly address prayers to their ancient gods.

Since the coming of the foreigner the Polynesians, despite their wonderful physique, have alarmingly decreased in numbers. Captain Cook estimated the population of the Hawaiian Islands at 420,000; to-day there are only 24,000 Hawaiians of pure blood. The Tahitians numbered 150,000 in 1774, fell to 17,000 in 1880 and to 10,300 in 1899. During the last two decades of the nineteenth century the decrease has been in Tonga from 30,000 to 17,500; in the Cook group from 11,500 to 8,400; in Manakini from 1,600 to 1,000; and in Easter Island from 600 to 100. In the valley of Typee in the Marquesas, where Herman Melville was so kindly treated, from a tribe which formerly boasted 4,000 fighting men only a dozen wretches have survived.

Such a decrease can be only partly accounted for by the wars, massacres and raiding for the South American and Australian slave trade before this traffic was stopped. A more important cause is the introduction of diseases by foreigners. Sickness was almost unknown to the Polynesians prior to the coming of the foreigners, and consequently they lacked the toxin in their blood which renders other peoples partially immune. A mild disease has been known to carry them off by the thousands; a single epidemic of measles once destroyed a tenth of all the natives of the Hawaiian Islands. Their swift change of habits has also rendered them the victims of many plagues. The Polynesian is amphibious by nature and as much at home in the water as out of it. In his scant native costume he would quickly dry off upon emerging from the water and be no worse off for his bath. Having adopted the trousers and shirt of the European he still goes into the water with his clothes on, insisting that if clothes are good they are good *all* the time. The clothes remain wet after he emerges and bring a heavy toll upon life in the forms of pneumonia and tuberculosis. The replacement of the native hut by the wooden house has exposed the native to the same plagues. The hut, made of thatch, was always well ventilated because of the looseness of its structure; the wooden house, of which the native persistently refuses to open the windows at night, is close and stuffy. The prohibition of the joyous native pastimes by over-zealous missionary endeavor, together with the lugubriousness of some of the things taught him, has depressed the native, rendering him an easier prey to the ravages of disease. The introduction of rum and opium has been a calamity to him, weakening and degrading him more than "fire-water" has degraded the American Indian.

From every point of view the coming of the foreigner has been an immeasurable curse to the Polynesian. Left to themselves the Islanders could be living to-day in a paradise unvisited by the plagues, pestilence and calamities that attack mankind now the world over. Before the visitation of the European and the Asiatic their flowery isles set in the midst of dark blue seas were far removed from every beast of prey, every poisonous serpent, every malady rising from the congested slums of earth. The gentle people led a carefree existence, spending much of their time swimming, riding the surf, playing at their sports of wrestling, boxing and football, dancing their expressive folk-dances of love and goodwill.

How changed is it all now! From the east and from the west have come calamities. The mosquito, the rat, the mongoose have arrived; though there are still no snakes, some fool will doubtless

soon import a couple of rattlers. The crews of the ships brought syphilis, which among a people with loose ties of marriage was bound to rage terribly, the Chinese brought leprosy, a disease unknown in the islands prior to 1848, but now there are nearly a thousand victims of this terrible plague segregated on the island of Molokai in the Hawaiian group. The changed conditions of living have resulted in a holocaust of death from pneumonia and tuberculosis, while measles and smallpox have done their worst among a people unable to withstand them. The Polynesian is perishing. Stopped are the games and the hulahula dances, forgotten are the songs of the fathers. Yet a little while and the rippling flow of his language, more like music than like speech, will have vanished from the earth; soon the very "aloha" will be heard no more. The Polynesian understands his fate. With a smile half sad, half hopeless, he looks forward to the day when he will be but a memory among the race of men.

THE SCIENTIFIC IMAGINATION[1]

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IN books and articles touching on the psychology and logic of research, a certain confusion has frequently arisen from the use of terms like *intuition, illumination,* and *inspiration,* which seem almost to defy definition, as well as from an unwarranted use of terms like *imagination* and *conception,* regarding the denotation of which there is some approach to harmony among the recognized exponents of mental science.

Among the philosophers, Wundt, Bergson and James, for example, acknowledge—each in his own way, to be sure—a close relationship between the imagination and the memory. Both of these mental processes admit of analysis into simple sensory elements. Reproductive imagination differs indeed from memory only in so far as it is unaccompanied by a sense of repetition. The productive, or creative, imagination, though it differs from the reproductive in the freedom with which it manipulates and rehandles sensory data, is nevertheless as dependent as it on the materials furnished by the eye, ear and other sense organs. We may rearrange and recombine the data supplied by sensation and retained in consciousness; we can create nothing absolutely new.

Nearly all of the chapter on imagination in James's *Principles of Psychology* would be equally relevant in a discussion of the memory. The point of view of this eminent philosopher and psychologist is so opposed to the views of writers like Tyndall and Pearson, who are inclined to identify the scientific imagination with creative thought in general (which it is our purpose to analyse), that it seems worth while to examine in some detail the phenomena of retention and recall, and, by differentiating one type of memory from another, obtain a clue to the various types of imagination in the strictest sense of that term.

Cases of remarkable powers of visual recall have been put on record by James. One of these he quotes:

[1] This is the first of a series of lectures on the "Psychology and Logic of Research," given before the Industrial Fellows of the Mellon Institute of Industrial Research of the University of Pittsburgh, February 14—May 2, 1922.

The more I learn by heart the more clearly do I see images of my pages. Even before I can recite the lines I see them so that I could give them very slowly word for word, but my mind is so occupied in looking at my printed image that I have no idea of what I am saying, of the sense of it, etc. When I first found myself doing this I used to think it was merely because I knew the lines imperfectly; but I have quite convinced myself that I really do see an image. The strongest proof that such is really the fact is, I think, the following:

I can look down the mentally seen page and see the words that *commence* all the lines, and from any one of these words I can continue the line. I find this much easier to do if the words begin in a straight line than if there are breaks. Example:

Étant fait ... .
Tous . ...
A des . . ..
Que fit . . . .
Céres . . . .
    Avec .. . .
Un fleur. . .. .
    Comme . ...

(*La Fontaine*, *S*. iv.)

In an experimental study undertaken by the writer a group of ten college students were asked to memorize words and sentences in Italian, a language which none of them had studied before, and of which the experimenter was also fairly ignorant. Each of the eight exercises, employed within the space of two months, consisted of ten detached words and of about fifty words connected in sentences. The procedure was to place typewritten sheets of the words and sentences, with their translation, before the students for twenty minutes. The sheets were then collected and all copies and notes made during the study period were destroyed. Forty-eight hours later the members of the group were asked to write down all the words which could still be recalled. In the third exercise of this sort one student succeeded in reproducing correctly nine out of the ten detached words and all of the words in the sentences. The spelling, the punctuation, and even the use of accents were almost perfect. This student was a well-marked type of motor memory. She found it impossible to memorize anything effectively without writing it down. To hold a pencil in the writing position aided her to some extent to fix in memory an ordered statement of ideas. When she had tried to learn the Italian words and sentences by visualization, they seemed quite strange to her after the lapse of forty-eight hours; but, when she had copied them down, they were as old friends.

In the seventh exercise a second student succeeded in recalling the ten detached words with one mistake in spelling and, with remarkable fidelity, a song of eleven lines from an Italian opera.

He relied not on motor or visual, but on auditory imagery. He insisted at the beginning of the experiment on having the words and sentences read aloud. Later he was able, so he said, to surmise the sound of them. His mistakes corroborate his introspection concerning his type of memory. His spelling, punctuation and use of accents were less accurate than the first student's. He was able to give only the first syllable of a five-syllable word which was indistinctly pronounced by his rather imcompetent instructor. The spelling "luto" for "lutto" was probably also due to the experimenter's defective pronunciation of Italian. In one line of the song the student elided two words by doubling the initial letter of the second word, but without deteriment to the rhythm. In this same exercise a third member of the group was able to recall only fourteen words out of sixty-four. His impression that his mind is of the visual type is supported by the fact that all of the words definitely remembered occur in conspicuous positions in the exercise —the first line of a stanza, the end of a line, the beginning and the end of the list of words, etc.

If the claim is put forward that great scientific discoverers have been gifted with particularly vivid imagery, we must bear in mind the actual achievements of young people of college age submitted to definite tests. In this chance group of ten students, one, as we have seen, relying on auditory imagery, was able to recall sixty-four words out of sixty-four, while another, by means of kinæsthetic imagery recalled sixty-three words out of sixty-four. Remarkable as their performances were, these students were surpassed in the total experiment by a student who was conscious (as many of us must be even in such a simple experience as holding a telephone number in consciousness for a few moments) of relying on both auditory and visual imagery.

The address of the Irish physicist Tyndall on the "Scientific Use of the Imagination," delivered before the British Association in 1870, gives evidence of the functioning of his own imagination, and raises a number of questions in reference to the use of the imagination in scientific research. He is of the opinion that in explaining sensible phenomena we habitually form mental images of the ultra-sensible. He holds that the action of the investigator is periodic, and that the emotions play no inconsiderable part in the intellectual life. Tyndall quotes Sir Benjamin Brodie as stating that the imagination is both the source of poetic genius and the instrument of discovery in science. When, however, Tyndall says that, with experiment and accurate observation to work upon, imagination becomes the architect of the theories of physical science, he seems to pass from the consideration of imagination in the strict sense of the term to the consideration of the speculative

process involved in the setting up of hypotheses; and, when he claims that without the exercise of the imagination the conception of force would vanish from our universe and that causal relations would disappear, his enthusiasm for his theme has apparently rendered him oblivious of the distinctions between mental processes. "There is," he proceeds, "in the human intellect a power of expansion—I might almost call it a power of creation—which is brought into play by the simple brooding upon facts." After this sample of amateur psychology one is not surprised to hear the physicist speaking of a composite and creative power in which reason and imagination are united. Having confused the imagination with the reason, he invents a *tertium quid* that includes them both. The example of scientific thought which he gives, concerning the process of developing analogies between the wavelets on the surface of a pond, sound waves in water or air, and light waves in the ether, does not further the differentiation of the imagination and the reason. He regards as a product of the imagination the inference that the people by whom we are surrounded are possessed of reason because they behave as if they were reasonable. For him the world of sense itself, the phenomenal world of the physicist, is largely the outcome of things intellectually discerned, and is, therefore, dependent on the imagination. In short Tyndall imparts to the term *imagination* the maximum extension and the minimum intension.

Francis Galton's essay on *Mental Imagery*, 1881, provides an antidote for the extreme views of Tyndall. In this essay Galton expresses the conviction that scientists as a class are not good visualizers. When he questioned his friends of the scientific world, including Fellows of the Royal Society and members of the French Institute, he was amazed to find that few of them could picture to themselves things recently seen, such as the breakfast-table at which each had sat a few hours previously. When, however, Galton addressed himself to persons whom he met in general society, he obtained results altogether different. Girls, boys, women, many men, could recall sights like the morning's breakfast-table with photographic vividness and in their appropriate coloring and illumination. The power to visualize is more marked in the female sex than in the male and is somewhat more active in adolescent boys than in men. A study of the drawings of the Bushmen of South Africa and of the remains of prehistoric art indicates that the visual imagery of primitive man may be of an almost hallucinatory vividness.

Convinced, by his systematic investigation of the comparative dearth of visual imagery among men of science, Galton arrives at

the conclusion that habits of highly generalized and abstract thought, the pursuit of language and book learning, are antagonistic to the faculty of perceiving mental pictures. He admits, however, that there are instances in which persons see mentally in print every word uttered in a conversation or an address, and that the highest minds are probably those in which visualization is not lost but is held as a rule in abeyance, ready for use on suitable occasions. In fact, in later studies he records the remarkable visualizing powers of men like Professor Schuster, Flinders, Petrie, and the Rev. George Henslow, botanist. Mr. Henslow recognized that visual images, which he could summon at will, differed from the original perceptions, and that they were dynamic, undergoing changes, in many cases due to a suggestiveness, in the images, of something else. At times the images oscillated or rotated in a perplexing manner.

Karl Pearson in "The Grammar of Science," 1911, resembles Tyndall rather than Galton and James as regards the scope and range he ascribes to the activity of the imagination. According to Pearson the discovery of law is the peculiar function of the creative imagination. He declares that the man with no imagination may collect facts, but that he can not make great discoveries. After an elaborate classification of such facts has been made and their relations and sequences carefully traced, the next stage in the process of scientific investigation is the exercise of the imagination. Pearson, however, insists that it is the *disciplined* imagination (comparable, no doubt, with Tyndall's composite and creative power in which reason and imagination are united) that has been at the bottom of all great scientific discoveries. He also admits that the *classification* of facts is often largely guided by the imagination as well as by the reason. At the same time he maintains that all great scientists have, in a certain sense, been great artists, and by describing a work of art as concentrating into a simple formula a wide range of human emotions and feelings, he attempts to bring the products of artistic creation into line with scientific laws. It is evident that Pearson, while emphasizing the importance in research of the creative imagination, has not contributed substantially to its analysis and differentiation.

Reserving for later consideration the complex mental processes so boldly broached by Tyndall and Pearson, let us glance, in the spirit of Galton and James, at some of the evidence concerning the employment of imagery by the scientific discoverer.

Dalton seems to have relied on visual imagery; as has been remarked by others, his mind was of a corpuscular turn. In the early stages of his meteorological work he thought of aqueous vapor as made up of minute droplets diffused among the gases of the at-

mosphere. To the particles of these gases he ascribed definite form, and represented by diagram his idea of the constitution of the air. About 1803 Dalton began to picture atoms as of different sizes. He formed visual images of molecules of nitric oxide and nitrous oxide, of carbon monoxide and carbon dioxide, of ethylene and ethane. In his laboratory note-book during the autumn of 1803 he made entry of his symbols for hydrogen (○), oxygen (⊙), nitrogen (⦶), carbon (●), sulphur (⊕), and several of their compounds, as (⊙●), (⦶⊙), (⊙●⊙), (⦶⊙⦶), etc. Dalton could not accept with equanimity the less graphic method of representing chemical elements and compounds. As late as 1837 he wrote: "Berzelius's symbols are horrifying: a young student in chemistry might as soon learn Hebrew as make himself acquainted with them. They appear like a chaos of atoms . . . . and to equally perplex the adepts of science, to discourage the learner, as well as to cloud the beauty and simplicity of the Atomic Theory." Would the development of modern chemistry have proceeded more rapidly if the symbols of Dalton, which appeal to the imaginative thinker, had triumphed over the symbols of Berzelius, which appeal to the conceptual thinker?

Kekulé has left an intimate[2] record, worth reproducing *in extenso,* of his own experience as a scientific discoverer.

Genius has been spoken of, and the Benzene Theory has been designated a work of genius. I have often asked myself what, exactly, is genius, in what does it consist? It is said that genius recognizes the truth without knowing the proof of it. I do not doubt that from the most remote times this idea has been entertained. "Would Pythagoras have sacrificed a hecatomb if he had not known his famous proposition till he found proof?"

It is also said that genius thinks by leaps and bounds. Gentlemen, the waking mind does not so think. That is not granted to it. Perhaps it would be of interest to you if I should place before you some highly indiscreet statements as to how I arrived at certain ideas of mine. During my stay in London, I lived for a long time in Clapham Road in the vicinity of the Common. My evenings, however, I spent with my friend Hugo Müller at Islington at the opposite end of the metropolis. We used to talk of all sorts of things, mostly, however, of our beloved chemistry. One beautiful summer evening I was riding on the last omnibus through the deserted streets usually so filled with life. I rode as usual on the outside of the omnibus. I fell into a revery. Atoms flitted before my eyes. I had always seen them in movement, these little beings, but I had never before succeeded in perceiving their manner of moving. That evening, however, I saw that frequently two smaller atoms were coupled together, that larger ones seized the two smaller ones, that still larger ones held fast three and even four of the smaller ones and that all whirled around in a bewildering dance. I saw how the larger atoms formed a row and one dragged along still smaller ones at the ends of the chain. I saw what Kopp, my revered teacher and friend, describes so charmingly in his

[2] *Berichte der deutschen chemischen Gesellschaft,* 1890, pages 1305-1307.

"Molecularwelt"; but I saw it long before him. The cry of the guard, "Clapham Road," waked me from my revery; but I spent a part of the night writing down sketches of these dream pictures. Thus arose the structural theory.

It was very much the same with the Benzene Theory. During my stay in Ghent, Belgium, I occupied pleasant bachelor quarters in the main street. My study, however, was in a narrow alleyway and had during the day time no light. For a chemist who spends the hours of daylight in the laboratory this was no disadvantage. I was sitting there engaged in writing my text-book; but it wasn't going very well; my mind was on other things. I turned my chair toward the fireplace and sank into a doze. Again the atoms were flitting before my eyes. Smaller groups now kept modestly in the background. My mind's eye, sharpened by repeated visions of a similar sort, now distinguished larger structures of varying forms. Long rows frequently close together, all, in movement, winding and turning like serpents! And see! What was that? One of the serpents seized its own tail and the form whirled mockingly before my eyes. I came awake like a flash of lightning. This time also I spent the remainder of the night working out the consequences of the hypothesis. If we learn to dream, gentlemen, then we shall perhaps find truth—

"To him who forgoes thought,
Truth seems to come unsought;
He gets it without labor."—

We must take care, however, not to publish our dreams before submitting them to proof by the waking mind. "Countless germs of mental life fill the realm of space but only in a few rare minds do they find soil for their development; in them the idea, of which no one knows whence it came, lives as an active process." As I have told you before, at certain times certain ideas are in the air. We hear now from Liebig that the germs of ideas are like the spores of bacilli which fill the atmosphere. Why did the germs of the Structural and Benzene ideas, which have been in the air for a period of twenty-five years, find a soil particularly favorable to their development in my head?

Kekulé thought that the answer to his own question lay partly in the effect of his early study of architecture, which had imparted to his mind an irresistible need of sensory presentation. He could not rest satisfied with an explanation of chemical phenomena unless he could support it by means of definite visual imagery.

Kekulé's account of the functioning of his imagination seems to stand as a unique confession in the records of scientific discovery. The history of literary composition affords us, however, numerous parallels. Professor Dilthey of Berlin has gathered some of these together under the suggestive title "Poetic Imagination and Insanity." Some literary men, like Scribe, are gifted with vivid visual imagery, others, like Legouvé, are dependent for their success on auditory images. Scott,* Victor Hugo, and Browning seem to belong to the motor type. There is evidence in the case of Flaubert, as well as in that of Zola, that literary imagination may derive its data from the chemical senses. An analysis of the writings of poets like Marston and Helen Keller, defective in sight, in hearing, or in both, is of particular value in the study of literary

imagination. Artistic creation in general employs imagery in order to preserve or enhance sensory experiences and to convey to others the moods of the artist.

Is there any class of human being in whom the imagination is more held in control, more disciplined, more subordinated to the reason, than it is in the adult scientist? All the psychic processes, including instinct and inspiration (which has been described as a sort of unconscious imagination), are means of establishing useful relationships with men and things, and it is by no means surprising that the scientific discoverer, who grapples with difficult problems of adjustment, should bring the finest powers of the mind into play. The history of science assures us that the creative imagination is not the monopoly of the painter, sculptor, poet, philosopher, or theologian.

Special investigations of the mental characteristics of Kepler, Newton, Davy, Faraday, Claude Bernard, Ehrlich, Weismann and others must be undertaken before an adequate psychology of scientific discovery can be formulated. The nature of the data of each science, as well as the mental make-up of the individual discoverers must be made the subject of rigid investigation. Kekulé's pupil Van 't Hoff, who at the age of twenty-two wrote the essentials of *La Chimie dans l' Espace*, seems to have shared the visual imagination of his master. For Kolbe the idea that the arrangement of atoms in molecules could be determined appeared almost as fantastic as a belief in witchcraft or spiritualism. Berthelot was not less disdainful concerning Wurtz, the teacher of Van 't Hoff and Le Bel. When some friend told Berthelot not to take the atomic theory too seriously, atoms having no objective reality, Berthelot growled: "Wurtz has seen them!"

The imagination, predominant in one type of scientific discoverer and restrained or suppressed in other types, is at best only one phase of creative thought.

THE SHORTHAND ALPHABET AND THE REFORMING OF LANGUAGE

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EVERY writer of shorthand—and there are now legions of them—must have wished, not only that others could write with as much ease and rapidity as himself, but also that there could be as short and accurate a system of printing as he has of writing. Why should we not make use of the shorthand alphabet not only for short writing, but also for short printing (either by hand or press), and a short, direct means to the correct pronunciation of new words?

Isaac Pitman, who invented the system of shorthand now most generally used among English speaking peoples, entertained this idea, and approved it, but never applied it This paper presents an original plan for adapting the shorthand alphabet to printing, summarizes the results of an experiment in teaching children to read matter printed in this new form, and points out the tremendous educational and social advantages that would accrue if this new type of paper-language were in general use.

According to Isaac Pitman's analysis, there are forty sounds in the English language, twenty-four consonants, twelve simple vowels, and four diphthongs, or double vowels. Adopting (substantially) the Pitmanic symbols, we may represent these sounds as below.

CONSONANTS

= p as in pop
= b as in bob
= t as in tat
= d as in did
= ch as in church
= j as in judge
= k as in kick
= g as in gig
= f as in fife
= v as in vivid

VOWELS (SINGLE)

(The vertical line is not a part of the vowel symbol, but is used to represent any consonant stroke. A vowel symbol, as a heavy or light dot, stands for different sounds according to its position)

= a as in pa
= a as in may
= e as in we
= a as in all

(= th as in thick

(= th as in that

) = s as in sit

) = z as in zoo

= sh as in ship

= zh = z as in azure

= m as in mum

= n as in noon

= ng as in sing

= l as in lily

/ = r as in rare

C = w as in will

U = y as in yes

= h as in hay

= o as in go

= oo as in too

= a as in that

= e as in pen

= i as in is

= o as in not

= u as in much

= oo as in good

DIPHTHONGS (DOUBLE VOWELS)

= i as in lie

= oi as in boil

= ou as in foul

= eu as in feud

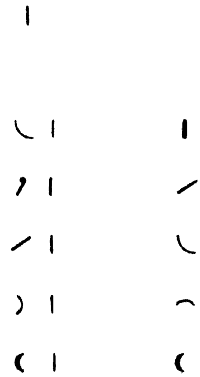
This gives us a perfect alphabet, neither redundant nor defective.

In writing shorthand, the consonant characters of a word or phrase are joined together, and the vowels are placed in a certain relation to the consonant strokes, that is, at the beginning, middle, or end of them. The vowel sign has a different sound according to its position. The plan here presented for adapting this alphabet to printing introduces two variations: the consonants are kept disjoined; and the vowels are placed, not at the beginning, middle or end of consonant strokes, but in high, middle, or low position with regard to the line of print. This adapted alphabet, and matter printed in it, will be referred to as Fonoline.

An illustration will make the matter thoroughly clear. Figure 1, which presents three charts used in teaching fonoline to children, shows the symbols used in the fonoline alphabet, and the appearance of words printed in fonoline.

Although various experiments have been made in teaching reading by means of a phonetic alphabet, it appeared worth while to teach a group of beginners to read fonoline, partly to find the degree of effort necessary to learn it, partly to discover whether there would be any difficulty in passing from fonoline to a-b-c English. Should we as a race ever wish to change our alphabet (as the Chinese are doing), this latter question would probably become very important.

Accordingly, fonoline was taught to a group of twelve pupils in a first grade, whose Stanford-Binet intelligence quotients ranged from 75 to 127, with a median of 87.5. In physique and power of application, they were probably somewhat below the



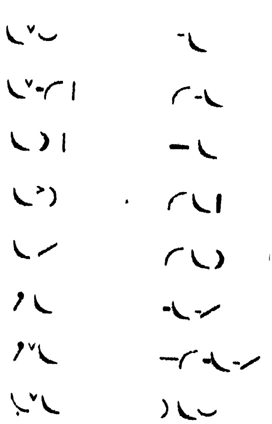


Fig. /. Three charts, reduced in size, used in the teaching of fonoline. The chart at the upper left shows the fonoline alphabet, omitting the symbol for the sound of sh, which was not used in the first grade vocabulary. The words on the other charts are as shown below, and in the same order.

<u>Words on Chart at Upper Right.</u>

at	an
cat	can
fat	Dan
hat	ran
rat	fan
sat	man
that	than

<u>Words on Chart at Left.</u>

vine	of
violet	love
visit	give
voice	lived
very	lives
have	over
hive	clover
five	seven

average. They were taught, in the East Stroudsburg State Normal Training School, by two cadet teachers and myself, no one of us having ever before taught a child to read. There was some difficulty also in procuring the necessary type and other materials for keeping the experiment going.[1]

At the end of a month (spending a little over an hour a day on the subject), twenty-three sounds had been introduced, and the pupils were attacking new words with fair success. A week later, the brighter pupils were separated from the rest and began

[1] In reporting this experiment, I wish to make acknowledgment of the receipt of financial aid by means of which it was promoted from the American Association for the Advancement of Science.

Acknowledgment of substantial assistance of a different kind is due to Mrs. La Rue, without whose help the necessary reading material could not have been composed, illustrated and printed.

reading such stories as "The Little Red Hen" without the aid of the teacher. At the close of eleven weeks, our advanced class had learned all the symbols, had read about one hundred fifty pages of the Fonoline Primer, and could readily master, independently, any new word of not more than five or six symbols (that is, five or six sounds when spoken), unless it involved some peculiar difficulty. As few words in the first grade vocabulary reach this length,

THE CAT AND THE MOUSE

A wee mouse was eating.

A cat saw her.

The cat said,

"I must have that mouse."

Then away she went.

FIG. 2. Showing fonoline used interlineally to aid in the introduction to a-b-c English. The words that have no fonoline beneath them had already been mastered by the pupils before reaching this story.

we thought it best to pass from this grade of attainment to the study of a-b-c English. At the end of fifteen weeks, the slower section also (containing, it will be remembered, some retarded pupils) having covered all their symbols and read over one hundred pages of the Primer, proceeded to the study of a-b-c English.

Passing from fonoline to ordinary English introduced practically no new problems except those which are always incident to the teaching of reading in English, and we of course used our "perfect" phonetic alphabet to aid in the mastery of the imperfect, partially unphonetic one. The first means employed was that of interlinear printing, placing the a-b-c English above and the corresponding fonoline just below as a key to pronunciation, as shown in the figure. As soon as a word had appeared in the a-b-c type a few times, it was left without the fonoline aid to pronunciation beneath it, whereupon the pupil either remembered it or was forced to go back and find it where it had last appeared.

At the close of the year, our pupils had accomplished, so far as we were able to judge, substantially the same amount of work in a-b-c English, after spending the first ten or fifteen weeks on fonoline reading, as they would have done had they spent the whole year on a-b-c English; that is, their achievements were on a level with those of preceding classes, the time devoted to reading remaining unchanged. Our advanced class won the special commendation of the State examiner, who had no knowledge of how the grade had been taught.

We are inclined to believe that fonoline forms a good introduction to a-b-c English, and that if it could replace the usual system of diacritical marking, time would ultimately be gained through its use. We consider it quite safe to assert that if a pupil of average intelligence and application were given a year of instruction in reading fonoline (especially if there were devoted to reading the two hours per day commonly assigned to it in our city schools), such a pupil would then be able to read anything (printed in that alphabet) which he was capable of understanding. Beyond reviews, no further work in reading would be necessary for one so taught except to train him in the apt expression of those thoughts and feelings which would come to him with maturity. And he would not only know how to read: he would be able to find in the fonoline dictionary any ordinary word that he could pronounce. Further, he could "spell," both orally and in writing (fonoline characters) any word that he could turn his tongue to.

Let us now give our attention to the educational and social advantages that would be ours if such an alphabet as fonoline were brought into common use. Let us keep in mind, too, that

fonoline is advantageous beyond any other phonetic alphabet; for it bears a unique relation to Pitmanic shorthand, the most speedy and efficient means yet devised by the human brain for passing its thoughts down through hand and pen and so recording them on paper.

First, then, does fonoline present an alphabet which adequately represents the sounds of spoken English? We can sum up this matter admirably by quotations from Max Muller: "What I like in Mr. Pitman's system of spelling is exactly what I know has been found fault with by others, namely, that he does not attempt to refine too much, and to express in writing those endless shades of pronunciation, which may be of the greatest interest to the student of acoustics, or of phonetics, as applied to the study of living dialects, but which, for practical as well as for scientific philological purposes, must be entirely ignored . . . . Out of the large number of sounds, for instance, which have been catalogued from the various English dialects, those only can be recognized as constituent elements of the language which in and by their difference from each other convey a difference of meaning Of such pregnant and thought-conveying vowels, English possesses no more than twelve. Whatever the minor shades of vowel sounds in English dialects may be, they do not enrich the language, as such; that is, they do not enable the speaker to convey more minute shades of thought than the twelve typical single vowels . . . . If I have spoken strongly in support of Mr. Pitman's system, it is . . . . chiefly because it has been tested so largely and has stood the test well."[2]

Next, if the number of our characters is correct, is their form satisfactory? As to the advantages of simplicity, perhaps the work of Broca and Sulzer can be accepted as authoritative. These investigators concluded that both our letters and the words of which they are composed would be more easily recognized and quickly read if they were simplified in form. "Practically," they report, "the recognition of a letter demands an expenditure of energy that is greater as its form is more complex. Thus we read a V, a T, or an L more easily than an E or a B. From the standpoint of speed of reading and also of the cerebral fatigue caused by the act it would be better to employ simpler letters than those now used. We have thus been led to seek the least complex possible forms, and we have concluded that, for capital letters, they are those shown in Figure 3. For the small letters, where there

[2] From an article in the *Fortnightly Review* of April, 1876, as quoted in *The Life of Sir Isaac Pitman*, by Alfred Baker, p. 206.

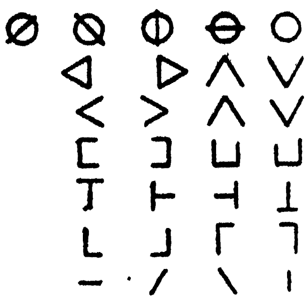


FIG. 3. Showing the simple capitals proposed by Broca and Sulzer

are two sizes, and two positions with respect to the line, the solutions are more numerous and some are shown in Figure 4.

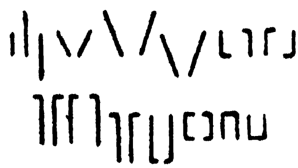


FIG 4 Simplified small letters proposed by Broca and Sulzer

"We do not wish here to go farther into this question and ask whether it would be worth while to change our present alphabet; but we desire only to point out that these characters, derived from the Phenician alphabet, are not scientifically as perfect as could

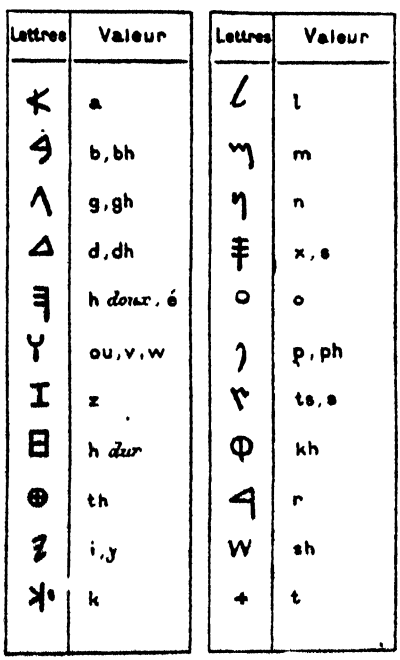


FIG. 5. Alteration of modern from ancient letters.

be wished. A glance at Figure 5 shows that all the changes made in transforming the old alphabet into ours are far from being simplifications.'"[3]

So far as capitals are concerned, whether simplified or not, they should be dropped altogether. In the teaching of fonoline, we omitted them and never missed them. Further, we were only embarrassed by them, as every teacher of primary reading is, when they appeared in the a-b-c English. The Germans distribute their complex capitals lavishly, to the exasperation of the reader (speaking for myself). The French tendency is better, to omit them as much as possible. Neither the writer nor the reader of shorthand commonly misses capitals or wishes for them. They only make him trouble. Had we grown accustomed from our youth to the use of small letters only, we should then have had the right attitude toward capitals, namely, that they are a useless and expensive luxury; and we should have rejected at once any proposal that they should be introduced into our language. As matters are, we ought to welcome the possibility of further simplifying our alphabet by reducing it from fifty-two characters to forty.

A further question of interest is, do words printed in fonoline have sufficient character and individuality to insure their quick recognition in rapid reading? Students of the psychology of reading seem to agree that glance recognition, as we may call it, depends chiefly on the length of a word, on its consonants, especially those that are so tall as to stick up above the general body of the word, and on its first letter or letters, which, as they strike the eye, serve as a kind of key to the part that follows. It is evident that words would have characteristic lengths and first-letter keys, no matter what alphabet were used. The great importance of the consonants in furnishing the skeletons of words and so giving them characteristic shape must long have been felt, even if not consciously reasoned out; for the Hebrews, centuries ago, left the vowels out of their words and still found them, for the most part, easily legible. The modern writer of Hebrew either fills in his vowels or omits them, as he pleases. So does the writer of Pitmanic shorthand. When writing under speed, he puts in only an occasional key vowel, yet finds his writing easily readable. The joined consonants of a word form an "outline" which flashes into his mind instantaneously when he hears that word pronounced, and which he recognizes at once when he sees it on paper.

I venture to assert that this advantage is carried over, in large

[3] This report was published in *La Nature*, Paris, February 18, 1904. The quotation and figures given above are taken from a translation printed in *The Literary Digest* of March 12, 1904.

measure, into matter printed in fonoline. The rapid reader, guided largely by context, as such readers always are, would find his words taking on such a characteristic consonantal shape that he would have little use for the vowels. The consonants would form the chief mass of the average word, and in the great bulk of cases would protrude either above or below their adjacent vowels. Yet if there were doubt in any case, as there might be when two words contained the same consonants in the same order, the vowels would be there to give their voice and settle the matter. But to vowels, generally, we should apply a rule in contrast with that which we apply to children: the vowels should be heard and not seen too conspicuously.

If it should prove desirable to indicate the accent of words, this could be accomplished by any of several simple methods, and in a manner which would cause printers no difficulty.

Let us now consider, but very briefly, how and how much we could shorten and enrich the work of the elementary school through the use of fonoline.

Learning to read would become so easy that many children would learn at home. (One of our pupils retaught a part of her fonoline lessons to her little brother.) At any rate, independent reading, on the part of the average child, would begin before he had spent more than a few weeks in school; and he could then advance, by silent reading, at his own pace, taking up one form of literature after another as fast as he was able to appreciate it.

The subject of spelling would disappear from our programs of study, leaving the time now devoted to it to be turned to some useful purpose. Like the Italians and the Spaniards, we should then have no spelling books in our schools.

The use of the dictionary would never have to be taught as at present; for since, with a phonetic alphabet, the pronouncing of a word is equivalent to the spelling of it, one could readily find in the fonoline dictionary any word that he could pronounce. Not only could any one master his own language quickly, but when foreign tongues were undertaken, he could use what would then be his native alphabet as an aid to the mastery of them also. A "phonetic transcription" would cease to be in any way formidable and would become wholly a help if one could indicate the pronunciation of strange-looking foreign words by using the familiar characters of his own alphabet. An enterprising and scholarly minister, father of one of our pupils, made use of her knowledge of fonoline to introduce her to Hebrew, in which language he was anxious to give her an early start. Pitman's shorthand has been adapted to twenty-one foreign languages, including Latin, and

also to Esperanto. Should any peculiar sound of a foreign tongue require a new symbol, then, it would very likely be ready to hand. Indeed, I do not consider it too wild a dream to hope that *the Pitmanic shorthand alphabet may some day serve as the common alphabet for all the languages of the earth.* I leave others to deduce the various results of this, and will here only remark that I should consider it a very long step toward a universal language, a step which, while suppressing no language, would very likely result in preserving the best elements of all.

In the subject of writing, fonoline, through its relation to shorthand, would secure advantages which no phonetic alphabet not so related to "the winged art" could gain for us. As matters are, we teach our pupils four different forms for each of our twenty-six letters, these are the printed small and capital letters, and the corresponding written forms. Of course, these four forms are sometimes similar, as in the case of the letter *o*; but again they are quite at variance, as with *d*, *e*, *g*, and *l*. With fonoline in use, all this extra and useless learning, together with the whole subject of writing as we now know it, would drop out of existence. Judging as well as I can from the very limited amount of writing fonoline which was done by our experimental class, I should say that, if pupils were given a regular daily period of such practice, they could by the end of the first year in school write anything, expressed in the words of the usual first grade vocabulary, which they would be likely to utter. With a very moderate amount of practice as compared with what is necessary for the learning of ordinary writing, they could write at least as fast as they now do the longhand, and probably considerably faster There are advantages of position and movement also, which conform more nearly to that which is naturally adopted by young children. For pupils of low mentality, this might be the limit of attainment.

For those who were ordinarily bright of mind and facile in learning, however, it would be but a small beginning. From fonoline the learner could pass, by the gradual and easy introduction of shorthand principles, to shorthand itself. This would be accomplished by such means as the joining of consonant strokes wherever convenient, and the introduction of shortening devices so familiar to the writer of phonography, such as the s-circle and the hooks at the beginnings and endings of strokes. The abbreviated signs for our most common words could also be taught, signs which would soon enable the pupil to write, in the shortest kind of shorthand, more than fifty per cent. of all the language he ordinarily used.

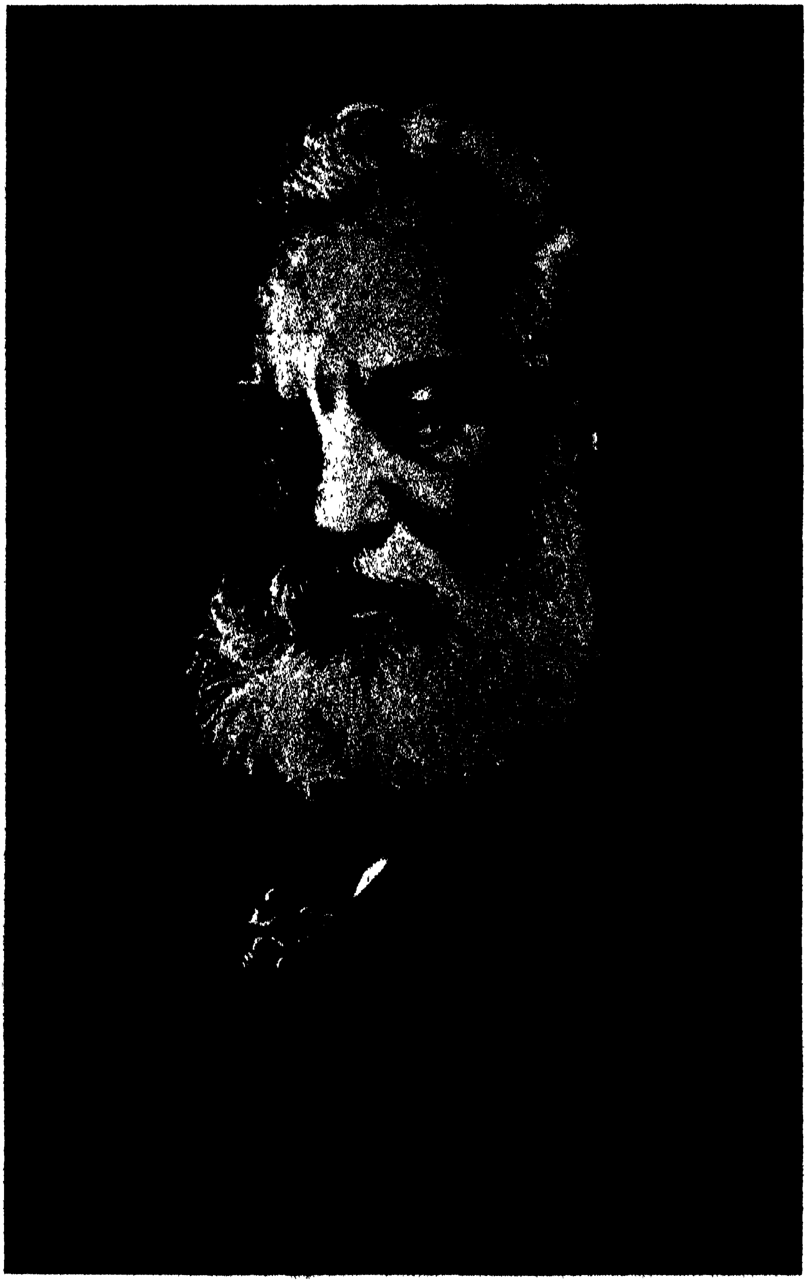
If such a course as I have described were preceded and accom-

panied by fonoline reading, and if we gave to it up through the grades the time which is now devoted to writing, I believe it safe to say that pupils would then be able to write no less than four times as fast as they now can with our cumbersome longhand, and with equal, or even greater legibility.

In the life outside of school there would result great savings in the printing of the language, in typewriting and linotyping, in teaching the feeble-minded, in the problem of Americanization, in progress foward a universal language, and in many other ways.

But the greatest argument, least appreciated because hardest to appreciate, lies, perhaps, in another direction. It is that a quicker alphabet, as we may call it, would make mankind more thoughtful and more social. The mathematician could never have made the progress he has in dealing with number and quantity had he not invented a shorthand method of expressing and working with them The physicist and the chemist have their shorthand. What scientist does not? Is not this one of the distinguishing features of the modern use of symbols, to concentrate a great bulk of meaning in such brief form that we can hold it all in one grasp of consciousness, reason with it in every way as an inclusive unit of thought work? But of this argument we can offer no more than a suggestion.

Had such an alphabet as fonoline been in common use for the brief span of a century or so, no argument to return to our present slow and cumbersome methods would be heeded for a moment.



—*Wide World Photos.*

ALEXANDER GRAHAM BELL

In whose death at the age of seventy-five years America loses its great inventor and man of science.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

BY DR. EDWIN E. SLOSSON
Science Service

WE WANT WATER

This is the season of the year when we appreciate the fact that our bodily substance is mostly composed of water. Lucky for us that it is, for water is not only the most abundant, but the most even tempered of liquids. It is slowest to cool and, what is of more interest just now, it is slowest to heat. It is this thermal conservation of water, otherwise known as its specific heat, that keeps us going regardless of the weather. For we can only live within the narrow rang of two degrees Fahrenheit, and it requires a delicate adjustment of the mechanism to maintain that temperature as we roam from the equator to the pole, or as the climates of these regions alternately roam over those of us who live in the north intemperate zone.

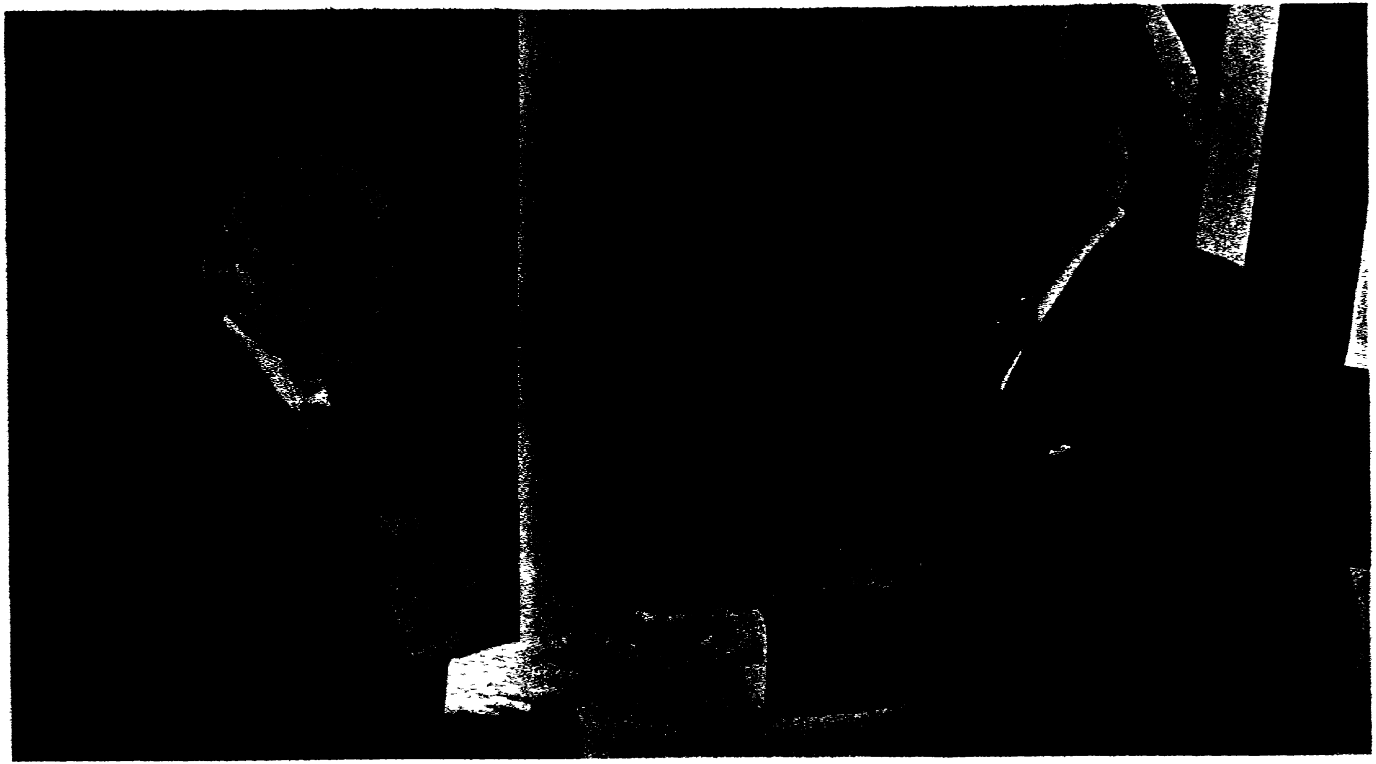
It is water that keeps all parts of the body at the same temperature in all weathers by circulation, and then in hot weather like this reduces the temperature by evaporation. So as a man on a pleasure excursion has to put a bill into his pocket from time to time to compensate for the sum imperceptibly evaporated in small change, so we require frequent invoices of water to keep up with the increasing retail outgo. The body in summer time is a steam engine, constantly taking advantage of the high rate of exchange between liquid and gas.

For water is twice blessed. It gives a blessing as it comes and as it goes. And the latter is the greater, though we are not so grateful for it. We appreciate the coolness of a glass of ice water, but it does us fifteen times as much good afterward as it escapes through a million pores. A cup of hot tea also may cool us off, for it takes away with it in evaporation from the skin fifty times as much heat as it brought to us.

Water is really what is wanted, although we add various flavors, call it by various names, and charge various prices for it. And it does not matter much what its initial temperature is, it will serve its purpose just the same. The only important thing is to get enough of it at all times, before meals, after meals, between meals and at meals One can hardly get too much of it, but one usually gets too little.

The regulation of the strength of the various fluids of the body is as nicely adjusted as the equilibrium of temperature. But both are dependent upon an abundant supply of water. An excess can be easily disposed of but a deficiency upsets the machinery. A pound of water a day is about what the body can manufacture in its internal laboratory from the hydrogen of the food and the oxygen of the air, but this is not nearly enough to run it. The automobilist cools down his combustion cylinder by wrapping it with water and keeping this in rapid circulation. We also are propelled by an engine using food as fuel in much the same way and we use the same device to prevent overheating. But we have to evaporate the water to get the full cooling effect and this tends to dry us up, to make mummies of us, to leave us stranded for want of water.

Our thirst is thus the longing of the salt that is left behind for the water that has departed. It is a sort of homesickness, a longing for an ancestral habitat. For Venus Anadyomene is a verified myth. All



—*Wide World Photos.*

SIR JOSEPH JOHN THOMSON, THE DISTINGUISHED ENGLISH PHYSICIST, RECEIVING THE FRANKLI
MEDAL FROM LORD BALFOUR

life sprang from the sea. And the tide that ebbs and flows through our heart is composed of much the same elements as the ocean from which it was originally dipped.

SHORT NAMES

When a man makes a new invention his work is not done. He should invent a new name for it. Here he is apt to fail for, being more of a mechanic than a philologist, he turns over the job to the Greek professor who manufactures one out of old roots So it happens that many a handy little pocket tool is handicapped by a name that wraps three times around the tongue. But the people refuse to stand for it.

Consider what a Babel like botch has been made of the job of naming the new art of photographing action Rival inventors, rival word-wrights, and rival systems of Greek transliteration precipitated a war of words in which the chief belligerents were animatograph, animatoscope, biograph, bioscope, chronophotography, cinema, cinematograph, cinematoscope, cineograph, cineoscope, electrograph, electroscope, kinema, kinemacolor, kinematograph, kinematoscope, kineograph, kineoscope, kinetescope, motion pictures, moving pictures, photo plays, tachyscope, veriscope, vitagraph, vitascope, zootrope, zoogyrograph, zoogyroscope, and zoopraxiscope.

But the people—they call it "the movies." It is not a great name, but it is better than some at least of those listed above.

If, instead of trying to load the new machine with a name implying that it had been invented in Athens or Rome, its godfathers had given it a respectable convenient name of one or two syllables like "volt," "kodak," or "velox," much of this confusion might have been saved. Think how many millions of dollars, years of time, barrels of ink and cubic miles of hot air would have been saved if "electricity" had been named in one syllable instead of five. We might even now cut it down to "el" except that by popular vote the six syllables of "elevated railroad" have been reduced to that handy term. So, too, the people have found a way to reduce "radiotelephony" to a single mouthful, "radio."

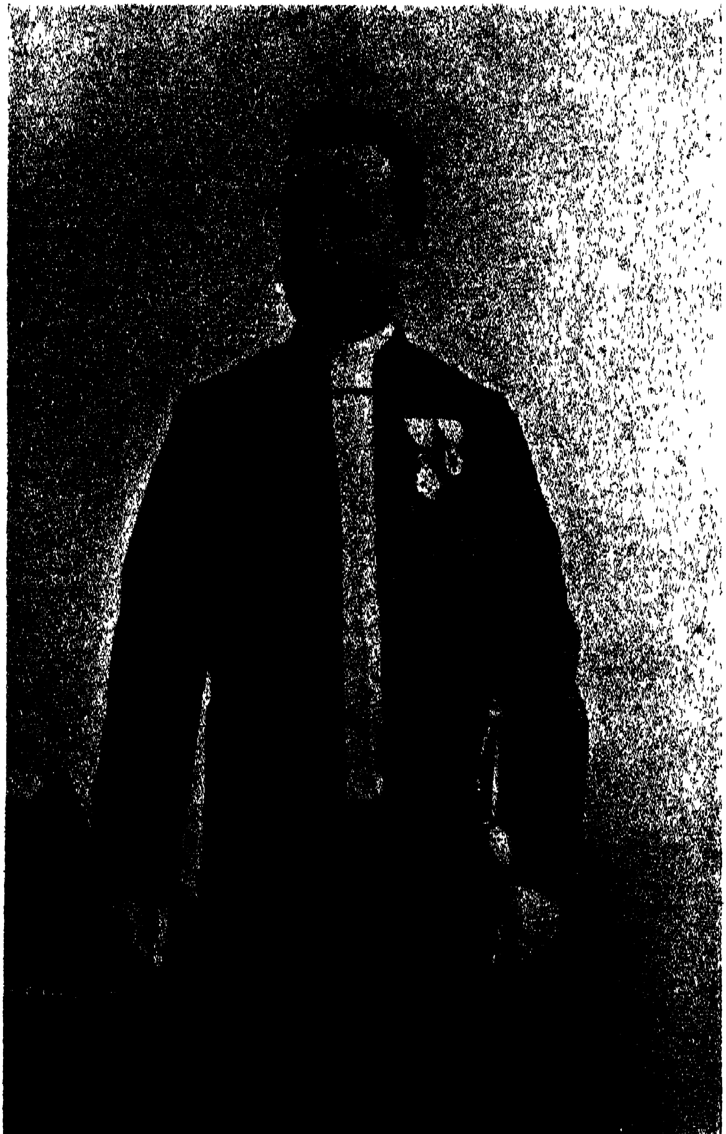
The lesson of it is that if the father of a new invention does not want to have his child called by a nickname let him give it a short and snappy name on the start

MEDIUMS AND TRICKSTERS

Those who believe in spiritistic phenomena call upon their opponents to disprove their hypothesis, and hold, rightly enough, that if ninety-nine mediums are merely tricksters, it does not prove that the hundredth is not genuine It is, of course, impossible to prove the universal negative of such a proposition It is merely a question of probabilities. We can merely say that if spirits do return, it is extremely unfortunate that they can only return under those conditions which are most favorable for deception.

What these conditions are we can learn from the practices of amateur and professional conjurers. Let us approach the matter from another starting point than is usually adopted. Instead of speculating as to how departed spirits would manifest themselves to us, a matter which we can know nothing about, let us consider what a trickster would do if he wished to deceive the public into thinking that he was possessed of spirit power, a matter on which we have unfortunately a great deal of information. What conditions would he impose? What methods would he use? The following are the chief characteristics of such fraudulent manifestations:

(1). Darkness. The less the light



EDMOND PERIER

In whose death France loses a distinguished zoological leader. Mr Périer, who was director of the Paris Museum of Natural History, is photographed in the official dress of members of the Paris Academy of Sciences

the more remarkable the manifestations is the general rule.

(2). Distraction of attention This is the chief reliance of the parlor and stage magician. The most striking things in the seance room occur after the sitters are tired of watching.

(3). Unexpectedness. An experimenter lets us know what effect he is trying to get, and even if the experiment does not work he does not palm off some entirely different phenomenon and claim he has succeeded. The feats of the conjurer—and of the medium—are capricious and unforeseen. That is why trickery can not be guarded against by precautions in advance.

(4). Control of conditions. The conjurer and the mediums alike insist on having lights, furniture, sitters and apparatus arranged to suit themselves. On the other hand, the primary requisite of an experiment is the control of conditions. It is therefore, incorrect to speak of experiments with mediums. They are usually merely observations, and that under circumstances most unfavorable to correct observation.

(5). Suggestion. This is the main reliance of the magician, next to distraction of attention. He palms a coin while pretending to throw it into a hat or into the air. Our eyes follow the motion of his hand and interpret it according to the intent. It is easy under favorable circumstances to cause collective hallucinations of smell, sight or sound. Our sense of hearing is particularly liable to be deceived as to the character and direction of a sound, such as the raps and scratches which are the commonest of mediumistic phenomena.

(6). Concealment. A prestidigitator for his most difficult tricks requires some kind of a table, shelf or screen, but he rarely demands so convenient a shelter as the medium's cabinet or curtain.

(7). Tied or held hands The releasing of hands and feet when they are bound, knotted and sealed is the cheapest of tricks I have seen a man handcuffed by a policeman, tied in a bag and thrown into the river, yet he came to the surface promptly with his hands free

(8) Involuntary assistance The respectable and well-meaning gentlemen whom the audience select to represent them on the stage do not interfere with the magician On the contrary, they often aid as well as give countenance The magnetic girl who used to throw strong men about the stage was really utilizing their strength, not her own Where several persons have their hands on a table it is impossible to prevent their taking an active part in its motion

(9) Emotional excitement. An experimenter must preserve a cool and somewhat detached demeanor. Now, even the most convinced skeptic can not witness unmoved such violations of natural law as these, purporting to prove the existence of another world, and especially the presence of his deceased friends and relatives. The photographs taken of the seance room show us not merely that the table is suspended in mid air, but that the witnesses, watching it with bulging eyes, open mouths and strained attention, are incapable of critical observation.

In these nine points and others the conditions of successful trickery and the conditions of the seance are the same. For that reason and others most scientists do not think it worth while to spend their time on spiritualism.

MIND-CLEANING TIME

Housecleaning time, when every article of furniture from cellar to garret is handled and dusted, occurs traditionally each spring. An annual purification of the spiritual nature, when we overhaul and furbish up our morals, is set by all the churches.

We are urged to subject ourselves to periodic physical examinations.

Yet it is quite as important to keep our minds in good condition as our houses, our consciences or our bodies. Error is as contagious as disease A false belief may make more trouble in the world than a wrong intention.

Vacation is a good time to over haul your brain from the frontal lobe to the cerebellum Review your axioms, revise your postulates, and reconsider the unexpressed minor premises of your habitual forms of logic. All your reasoning, however correct, all your knowledge, however great, may be vitiated by some fundamental fallacy, carelessly adopted and uncritically retained. Get a lamp and peer into all the dark corners of your mind No doubt, you keep the halls and reception rooms that are exposed in conversation to your friends in fairly decent and creditable order. But how would you like to let them look into your cerebral garret and subliminal cellar, where the toys of childhood and the prejudices you inherited from your ancestors mold and rot?

Hunt out and destroy with great care every old rag of superstition, for these are liable at any time to start that spontaneous combustion of ideas we call fanaticism against which there is no insurance The bigger the brain the more dangerous such things are, for they have the more fuel. A little decaying superstition in the mind of a great man has been known to conflagrate a nation.

Errors breed errors. They multiply like microbes, especially through neglect. A single false belief may infect all the sound facts you pile in on top of it. Better an empty room than a rubbish heap. In the words of our American philosopher, Josh Billings, "it is better not to know so many things than to know so many things that are not so."

Go systematically through your intellectual equipment and see wherein it is deficient. Add annuals to your mental cyclopedia. Pick up each one of the sciences where you left off at school and bring it down to date. Look over the fields of art and literature to see what you have missed or misconceived. Don't let your sociology get too far behind the age See that your philosophy and psychology bear the same date as the calendar Examine your religious creed in the light of modern knowledge to see if it needs revision. Take down the atlas and consider how long it has been since you heard from each country Visit the planets in turn Take another view of ancient history through the telescope provided by modern scholarship

This inspection of one's stock of ideas is necessary because they do not keep as if they were in cold storage They do not remain unchanged when stored away and neglected. There is a lot of thinking going on in our brains that we do not know anything about Ideas are apt to sprout or spoil, like potatoes in a cellar. Facts will ferment from yeasty thoughts until they intoxicate the brain. Falsehoods generate ptomaines, poisoning the mind and producing inexplicable disease and death. You can not be too careful. Clean out your mind at least once a year.

SCIENTIFIC ITEMS

WE record with regret the death of Alexander Graham Bell; of Simon Nelson Patten, long professor of political economy in the University of Pennsylvania; of Jokichi Takamine, the industrial research chemist; of Jacobus Cornelius Kapteyn, professor of astronomy at Groningen; of Wilhelm Wislicenus, director of the chemical laboratory at Tübingen; and of Jacques Bertillon, the French statistician.

// THE SCIENTIFI MONTHLY

OCTOBER, 1922

THE CONSERVATION AND PROPER UTILIZATION OF OUR NATURAL RESOURCES[1]

By Dr. BARTON WARREN EVERMANN
DIRECTOR OF THE MUSEUM OF THE CALIFORNIA ACADEMY OF SCIENCES

THE natural resources of the United States are the richest and most varied of any country in the world. It is only necessary to call attention to our great coal and oil fields and natural gas, our varied mineral resources, wonderful forests of hard and soft woods, our multitude of species of wild game mammals and birds and fur-bearing animals, the hundreds of species of useful insectivorous and predaceous birds, and the rich fisheries of our Atlantic, Gulf and Pacific coasts, Great Lakes and other interior waters, to enable us to realize that our country has been exceedingly blessed in this regard.

And this very richness of natural resources has had much to do with making us the most short-sighted, the most extravagant and the most wasteful people in all the world. There is not one of our natural resources which, in the beginning of the development of the country, was not handled in very wasteful ways; in numerous instances so wasteful and destructive that the resource was wiped out almost, if not quite, entirely. Such were the Buffalo, Wild Pigeon, Atlantic Salmon, Wild Turkey, Gray Squirrel, Sturgeon, Sea Otter, natural gas, white pine and many others that might be mentioned.

It is now too late to do anything to correct the mistakes with some of the species that were once valuable assets to our people, because they are now entirely extinct, or are species whose well-being depends upon an environment which has passed and can not be restored. But there are many species of the native flora and fauna with which it is not too late and which, with proper care,

[1] Presidential address delivered June 22, 1922, at the Salt Lake City meeting of the American Association for the Advancement of Science.

can again be restored to something like their former abundance and usefulness.

The Forests

It was my good fortune to be brought up in the middle Wabash Basin, a region in which was then found perhaps the greatest hardwood forest the world has ever seen. Great oaks, hickories and elms, each of several species, magnificent sycamores, black walnuts, yellow poplars or tulip trees, splendid gray ash and swamp ash, three or more species of maples or sugar-trees, poplars or cottonwoods of half a dozen species, some of them magnificent trees, and, scarcely less in size and value, but not at all in interest and beauty, were many others that might be named if time permitted. No other forest so rich in species and individuals of commercially important and esthetically interesting trees has ever existed elsewhere in the world. And the pity of it all is that the pioneers of those days never realized what a wonderful asset they had in their great forests. They regarded the forest simply as a source of supply for firewood and the small amount of logs and lumber they needed for buildings, fences and the like, and as something that must be got rid of as soon as possible in the interests of agricultural development.

I have seen many a barn built largely, if not wholly, of black walnut logs; and I later saw some of those same barns and stables torn down and the walnut logs hauled away to the sawmill to be converted into high-priced lumber. On my own father's farm and on many others in the same county, there were thousands of walnut rails in the Virginia worm fences with which the farms and fields of those days were enclosed. In the early seventies, black walnut became so valuable that even the stumps were dug out and shipped away to furniture manufacturers.

The wastefulness in clearing the land was almost beyond belief. Little or no effort was made to save any of the timber except that needed for immediate use. When a piece of land was to be cleared, all the trees were first girdled thus creating a deadening. Then the trees of whatever kind were felled or burnt down, after which the trunks were cut or burnt ("niggered off") into logs of lengths for convenient handling. With teams of horses or oxen, these logs were then snaked around and piled into great log-heaps, four logs on the ground constituting the bottom layer, three on top of these, two on top of them, and finally one at the top. Each log-heap would thus consist of 10 logs, with small limbs, chunks and trash filling the interstices to serve as kindling when the heaps were to be burned. So heavy and dense was the forest that there would be scores of these great heaps on every acre, each heap made

up of logs of the very finest quality whose value to-day would be many times that of the land on which they grew.

The bringing of the land under cultivation was essential to the development of the country. This, of course, necessitated the removal of the forest; heavy forests and corn-fields can not thrive on the same ground at the same time. Nevertheless, the methods were most wasteful, but a valuable lesson can be learned therefrom. Many of the important forestry and agricultural problems that confront us to-day could have been avoided or never would have arisen, if the pioneers could have foreseen the results of their wasteful methods.

That there are many very serious problems is well known to every one who has given the matter any attention. According to the U. S. Forest Service, three fifths of our primeval forests are gone, and the timber remaining is being consumed four times faster than it is being replaced. Several of our principal forest regions are already completely exhausted as large producers of wood products. The injury is felt through the process of regional exhaustion, compelling recourse to more distant and less accessible regions, with the inevitable increase in cost of production, higher freight rates, and greater cost to the consumer.

While the depletion of our forests for legitimate ends has been great, it is the devastation of the forests that has been most serious. The Forest Service tells us there are 326 millions acres of cut over timberlands in the United States. On 81 million acres there is practically no forest growth, and this is the result of forest fires and methods of cutting which destroy or prevent new timber growth. There were in 1919, 27,000 recorded forest fires which burned over 8 million acres. A large additional acreage is burned each year of which there is no record. The area of idle land is being increased 3 to 4 million acres annually as the cutting and the burning of the forests continue. The Forest Service estimates the forest land in the United States not required for any other economic use at 463 million acres, an area that would provide an ample supply of wood if kept productive. Depletion has resulted not from using our timber resources, but from a failure to use our timber-growing lands. The real solution of the timber problem is to grow new forests on the cut-over and the burnt-over ground and protect the forests we still have. There must be a concerted effort on the part of the Federal Government, the states and private owners to stop the devastation of our remaining forests and to put our idle forest lands at work growing timber. As the Forest Service well says, it is inconceivable that we should go on using up our forests without making provision for growing new to replace the

old. The policy should be to maintain timber production on somewhat the same footing as in Scandinavia and France; this should become an established national policy and practice.

The national forests contain several million acres of forest land so severely burned over that it can not be restored without replanting. To restore this land to timber production is an immediate Federal responsibility. Tree-planting is most urgent on denuded watersheds from which water is obtained for power, irrigation, or municipal use.

The cutting off of the forests, but more particularly the undergrowth, has been far-reaching in its disastrous results. The effect upon the animal life of the forests themselves has been marked indeed. Many species of mammals, birds, reptiles and amphibians that found a congenial home in the heavy forests of Indiana and other upper Mississippi Valley states 50 years ago are now rarely or never seen; many of them are now extinct in those regions. Many species have disappeared not because of overhunting but chiefly because of the destruction of the forest cover which was essential to their protection from their various enemies and to their habits of life.

Another deplorable result is that upon the streams of the country. While the removal of the forest cover has probably had no appreciable effect upon the rainfall, it has had a very decided effect upon the run-off. With the forest cover the rain was held by the underbrush until much of it soaked into the ground and the run-off was slow and gradual. The streams therefore had a relatively even flow throughout the year. Now, with the forest cover gone and the land under cultivation, the run-off is rapid, and the streams are very uneven in their volume; raging torrents at times, often spreading beyond the banks after heavy rains, and in the dryer season reduced to series of stagnant pools. And what a change in the beauty of the stream! Then a beautiful, stately flowing stream of clear, cool, pure water, the banks heavily wooded and with underbrush of many interesting shrubs, and greensward here and there, and the water teeming with fishes of many kinds; now at times merely a sluggish, weed-choked thing as devoid of beauty as it is of fish.

Fortunately, it is still possible greatly to improve these streams and bring them back to something of the beauty of earlier days. This can be done by reserving from cultivation a narrow strip of ground along each side of the stream and planting it with perennial plants, shrubs, bushes, vines and trees that will hold the immediate banks of the stream in place and at the same time check the run-off, conserve the moisture, shade the stream, and increase the beauty

of the stream amazingly. This strip can be any width, the wider the better of course, but it ought to be at least 30 yards.

A little attention of this kind will greatly increase the stability and beauty of the stream; it will also be helpful to the fish life of the stream by giving the fish more protection, shade and food. It will be of benefit to the farmers and others along the stream in that it will protect their land from overflow and from destructive erosion.

Another regrettable result of the cutting of the forest and the undergrowth and the draining of the marshlands and the small woodland ponds, is the extermination of many species of the native flora. Among such species that were formerly more or less abundant in the upper Mississippi Valley that may be mentioned are the Wild Red Plum (*Prunus americana*), the Wild Cherry (*Prunus serotina*), Black Haw (*Viburnum prunifolium*), Red Haw (*Cratægus pyrifolia*), Pawpaw (*Asimina triloba*), Leatherwood (*Dirca palustris*), Kentucky Coffee-tree (*Gymnocladus canadensis*), Spice-bush (*Benzoin æstivale*), and various species of orchids, particularly the showy Ladies'-Slipper (*Cypripedium reginæ*). These interesting and beautiful species that added so much of grace and beauty and charm to the virgin forest are now rare indeed, and in some localities entirely extinct. And the regret is all the greater because of the fact that every one of them could have been preserved in considerable abundance if only a little foresight and care had been shown.

Effect of Deforestation upon the Fishes of Our Streams

The effect upon the streams of the cutting away of the forests has been very great, as already pointed out, and it has been equally great upon the fishes of the streams. In order that a stream may support a large and varied fish-fauna it must be somewhat uniform and constant in its character. A stream which at one time is a raging torrent and at another season a series of isolated stagnant pools, does not permit the development and maintenance of a fish-fauna rich in species or individuals. This fact may be readily appreciated if we compare a typical Mississippi Valley creek or river with any typical stream in California where all the streams are subject to great extremes. In almost any small stream in Indiana, there may be found not fewer than 30 to 40 kinds of fishes, a greater number than occurs in all the streams of California or Utah. But the Mississippi Valley streams are rapidly becoming in this respect like those of California—streams of unstable and extreme conditions, and fish-life is decreasing correspondingly. The food and game species, of which there were a score or more originally, are now very scarce. Some of them have entirely disappeared, while others are so rare as to afford little or no sport for the angler.

The United States Forest Service and the National Parks Service in their administration of the National Forests and the National Parks respectively are to-day the most efficient and most effective forces working for the conservation of the forests, the water supply and the natural scénic and esthetic beauty of our country. However, the tendency of the National Parks Service to graft on to some of the National Parks various Coney Island alleged attractions is deplored. National parks should be maintained as *natural* parks and not be marred by artificiality of any avoidable kind.

Drainage of Swamps, Ponds and Lakes

Not until recently have we come to realize that the drainage of swamp-lands, marshes, ponds and small lakes may be fraught with great danger to certain species of animals and plants of economic importance, and that the results are often harmful rather than beneficial to agriculture. A writer (A. G. Reywall), in a recent issue of the Bulletin of the American Game Protective Association, asserts that the havoc wrought in some sections by drainage projects has been so great as to arouse indignation and resentment among people who realize that such areas have important functions in relation to agriculture and the general public welfare. The assumption that the area which it is proposed to drain will prove valuable agricultural land is not always warranted. This writer says:

> The rivers of the country, with their small tributaries, are the natural surface channels for carrying off surplus rainwater. A part of this water works through porous strata to varying depths and is discharged at the surface through springs which are the natural outlets of underground drainage. Small lakes and marsh areas are undoubtedly the fountain heads of great numbers of springs and wells which are so essential to the welfare of the community. These lake and marsh areas also act as great check-basins or natural reservoirs in which are held back enormous quantities of water resulting from heavy rains and rapidly melting snow, allowing it to flow off gradually and thus effectively lessening the danger of floods.

The whole country has been appalled by reports of disastrous floods in which great numbers of lives were lost and millions of dollars' worth of property destroyed. (As I write, the daily papers are telling of great floods in the Mississippi which have rendered more than 75,000 people homeless and destroyed millions of dollars' worth of property.) The destruction of the forests and the drainage of natural catch-basins, such as marsh areas, ponds and small lakes along the waterways, make such catastrophes inevitable, so that at times of unusual rainfall millions of tons of water sweep down the valleys, leaving fearful devastation behind.

In the State of New York it is now planned to establish numer-

ous great reservoirs to hold back the flood water and to regulate the flow of streams that have their sources in the Adirondacks. It will cost millions of dollars to construct reservoirs to hold back water which could have been conserved naturally had the public interest been safeguarded as was easily possible.

Lake and marsh areas in their natural state have numerous important uses. In the first place, they conserve the run-off and establish a relatively uniform stream-flow, as I have already shown. In the second place, they provide resting, feeding, and breeding places for many species of waterfowl and other species of birds. They also provide appropriate environment for the muskrat and other species of fur-bearing animals. With proper management these marshes will yield annually many thousands of dollars in furs. In one marsh of 4,000 acres, in 1913, over 12,000 muskrats were taken valued at several thousand dollars. This marsh has since been drained, and the muskrats exterminated, but only about 100 acres of the area has been found fit for cultivation.

As a glaring example of serious mistakes in drainage operations, I may call attention to the Kankakee River in northwestern Indiana. This was until recently one of the most famous wildfowl shooting regions in America. The marsh through which the Kankakee flowed was some 50 miles long and five to 10 miles wide. Wild ducks and wild geese in enormous numbers annually visited these marshes, some to nest and rear their young, others to rest and feed while on their spring and fall migrations. Muskrats, mink, and other fur-bearers also were there in abundance, and the waters teemed with the finest of food and game fishes.

Recently these marshes have been drained and it has developed that the whole marsh area is sand with a coating of vegetable matter too thin to make a soil of any fertility. Several acres that were sown to rye produced absolutely nothing, and it is now generally recognized that nothing can be grown on this land.

Hundreds of thousands of dollars almost absolutely wasted in draining land which was found to possess very little value for agricultural purposes, and which will probably have to be irrigated at great expense to make it of any considerable value for any purpose. And we now have, or will have, a barren sand-dune region non-productive in any useful way, in place of a region which, before destroyed by short-sighted man, was one of the richest in America in wild fowl, fur-bearing animals and food and game fishes, to say nothing of its esthetic and recreational value.

This deplorable result could have been avoided if a careful soil-survey of the region had been made before deciding to drain the Kankakee marshes.

The State of Minnesota had a very similar experience, but a law has now been enacted to prevent any repetition of such mistakes by requiring the approval of the State Conservation Commission before any large areas may be drained.

It is frankly admitted, of course, that most of the swampland possesses agricultural value when drained, but much of it will have little or no such value. The point I wish to make is this: swamp lands, ponds and small lakes *as such* have uses and values that must not be ignored. I have noted that a proposition has been made recently to drain practically all of the thousands of small lakes in Wisconsin. Should this be done there will probably be more corn, cabbage and hogs in Wisconsin than now, but there will be less of beauty and the appreciation thereof.

Federal Protection of Migratory Birds

Researches by the Bureau of Biological Survey have demonstrated the importance to agriculture of our migratory birds. That insectivorous birds annually save millions of dollars to the farmer by destroying insects injurious to crops is no longer questioned. That millions of dollars of damage have been done to our forests by insects formerly kept under control by insectivorous birds is also well known. The esthetic value of our native birds must not be forgotten—the inspiration and stimulus which they give to the moral sense, the charm and beauty they give to nature and which enter so largely into the life of the people—these are values that can not be overestimated.

It is a great pleasure to call attention at this time to one illustration of intelligent appreciation of the value of our birds. If you will go down near the Temple here in Salt Lake City you will find a graceful Doric column 15 feet high. On the top of the column rests a granite sphere on which two gulls are in the act of lighting. If you read the inscription on the base you will learn that, in the spring of 1848, a terrible plague of crickets threatened total destruction to the growing crops which the Mormons had planted. Nothing which the people could do could stop the vast hordes of insects. Just when the situation seemed entirely hopeless, great numbers of gulls came over from their breeding grounds on Hat Island in the Lake and began devouring the crickets. In a short time the millions of crickets were destroyed and the crops were saved. The people, realizing that the gulls saved the day, expressed their gratitude in an unique and beautiful manner. And we have here to-day the

"Sea Gull Monument
Erected in Grateful Remembrance
of the Mercy of God to the
Mormon Pioneers."

Who can claim that the wild birds are not our friends, or that man is not sometimes appreciative!

Not until within recent years have many really effective steps been taken in this country to protect our birds. Only a few of the states had any protective laws whatever. Finally laws began to be enacted regarding game birds, but no attention was paid to the insectivorous and other non-game species. But the laws enacted by the various states were lacking in uniformity. Nearly all permitted spring shooting and market hunting, the open season was very long and the bag limit, if any, was ridiculously large.

The Lacey Law

One of the first Federal laws in the interest of bird protection was the Lacey Law enacted in 1909. The important provisions of this law are the ones regulating the shipment of game in interstate commerce and that regulating the importation of birds and mammals from foreign countries.

Migratory-Bird Law of 1913

Beginning with 1904, various attempts were made to secure Federal legislation for the protection of migratory birds, but it was not until 1913 that any results were secured. In that year the Federal Migratory-Bird Law was enacted. This law gave the Secretary of Agriculture power to fix close seasons during which it would be unlawful to capture or kill migratory birds. One of the most important regulations under this act was that prohibiting spring shooting. This regulation has proved of enormous benefit. The effect was almost instantaneous. Waterfowl and other migratory game birds at once showed decided increase, and many remained to breed where they had not bred for many years.

The question of the constitutionality of this law was raised but before it was passed on by the Supreme Court the law was repealed by the enactment of more effective legislation in 1918.

The Migratory-Bird Treaty

On August 16, 1916, there was concluded at Washington between the United States and Great Britain a migratory-bird treaty for the more adequate protection of the migratory birds that visit the United States and Canada. This convention was ratified and became law December 7, 1916.

The making of this treaty is probably the most important single event that has ever occurred in the movement for the protection of migratory birds. Of a total of 768 species of birds recognized in the last (1910) edition of the A. O. U. Check-list of North American birds, 537 species are protected by this treaty; only about 220

species are not covered by the treaty; it is unfortunate that they, too, could not be properly included. Among those which are protected by the treaty are all the ducks, geese, swans, shore birds, plovers, snipe, cranes, and all migratory insectivorous birds. The treaty provides special protection for 5 years of wood ducks and eider ducks and for 10 years to the band-tailed pigeon, little brown crane and several other species. It makes spring shooting unlawful, and confines hunting to seasonable periods of not exceeding 3½ months for shore birds not given absolute protection, and other migratory game birds.

The Migratory-Bird Treaty Act

Although the treaty does not provide the machinery for its enforcement, it does provide that the High Contracting Powers shall enact the legislation necessary to insure its enforcement. Canada did so August 29, 1917, and the United States did likewise by passing the *Migratory-Bird Treaty Act* which was approved by the President July 3, 1918; and it has been well said that "the enactment of this legislation rounded out the most comprehensive and adequate scheme for the protection of birds ever put into effect."

Under this Act it is unlawful to hunt, capture, kill, possess, sell, purchase, ship or transport at any time or by any means any migratory bird included in the terms of the treaty except as permitted by regulations which the Secretary of Agriculture is authorized to make.

The constitutionality of the treaty and the treaty-act can not be questioned, for the Constitution provides that "all treaties made or which shall be made, * * * shall be the supreme law of the land; and the judges in every state shall be bound thereby, anything in the Constitution or laws of any state to the contrary notwithstanding."

The first regulations under the migratory-bird treaty act were prepared by the Secretary of Agriculture and approved by the President July 31, 1918. Certain amendments were adopted and made effective October 25, 1918.

The regulations are prepared by the Secretary of Agriculture, with the assistance of the Bureau of Biological Survey and an advisory board of 21 members representing all sections of the country. Regulations prepared with the great care which this implies are quite certain to give protection to the birds and at the same time meet the approval of the great body of sportsmen and others interested in bird protection.

The beneficent effects of this treaty were immediate. Reports showing a marked increase in ducks and other migratory game birds are coming in from all over the country. But as the ducks

increase in numbers it becomes increasingly evident that a few things yet remain to be done before these birds will have entirely adequate protection and before the poor man can get that good from the increase which he ought to enjoy. Realizing this, Senator New of Indiana and Congressman Anthony of Kansas have each introduced bills known as The Federal Public Shooting Grounds and Bird Refuge Act.

This is a bill providing for the establishing of shooting grounds for the public, for establishing game refuges and breeding grounds, for protecting migratory birds, and requiring a Federal license to hunt them.

The important things which it is hoped will be accomplished by this bill if enacted into law are the following:

1. To establish refuges or sanctuaries where ducks, geese and other migratory game birds may stop to rest and feed undisturbed when on their way north in the spring and on their return south in the fall, and where any that may be inclined to do so may be induced to stop to breed and rear their young.

2. To provide for issuing a hunting license at the nominal cost of $1.00 to those who wish to hunt wildfowl.

3. To provide public hunting grounds where anyone with a Federal license may hunt.

The necessity for the sanctuaries becomes more and more apparent every day. The draining of the marshlands, ponds and small lakes in many states is rapidly rendering those regions unattractive and unsuited to waterfowl, with the result that the birds pass over without stopping in many places where they formerly tarried for a time in the spring, many of them even remaining to breed, and in the fall going on south without even stopping for a day.

By establishing sanctuaries many birds would tarry in the spring to rest and feed, some would remain to breed, and in the fall, they would again tarry to feed, and the sanctuaries would then become good shooting grounds.

The Biological Survey estimates that at least 5 million people in the United States take out hunting licenses each year. It is believed that at least one million would take out the Federal shooting license. Anyone wishing a license can obtain it at his post-office. About a million dollars would thus be raised to be used as follows:

1. Not less than 45 per cent. for the purchase or rent of suitable land, waters, or land and waters, for use as public shooting grounds and migratory-bird refuges.

2. Not less than 45 per cent. for enforcing the provisions of

the migratory-bird treaty act and the Lacey Act, and for cooperation with local authorities in the protection of migratory birds.

3. Not more than 10 per cent. for expenses connected with issuing licenses, etc.

One of the excellent features of this law, if it becomes a law, is that all expenses connected therewith will be paid out of the fund resulting from the sale of hunting licenses. The expense of enforcing the Lacey Act and the Migratory-Bird Treaty Act will also come out of this fund. Congress will not need to appropriate any money at all.

Another excellent feature is that it will afford the poor man an opportunity to hunt waterfowl. Under present conditions practically all the good shooting grounds are owned or controlled by shooting clubs to which only men of means can afford to belong. The proposed law will give the poor man an equal chance with the rich man. The cost of the license is nominal; anyone who cares to hunt at all can afford to pay $1.00 for a shooting license.

It has been estimated that there are over 60,000,000 acres of government swamp land in the United States, much of which, even if drained, would have little or no agricultural value. Numerous wild fowl sanctuaries and public shooting grounds could be established in these swamp lands which would prove of inestimable benefit to migratory birds and at the same time afford splendid sport to thousands of people who enjoy a few days shooting each season. I understand that there is at the mouth of the Bear River in this state a large area of swamp land all ready to be made into a large refuge, and I further understand that the Governor and the people of Utah are strongly in favor of having this tract made into a Federal bird refuge and public shooting ground.

This is fine. There are doubtless many similar areas in the state, as there are in practically every state in the Union.

With the establishment of sanctuaries and public shooting grounds such as these in various parts of the country, the safety and conservation of our migratory game birds is assured.

Some of our migratory birds do not belong with the waterfowl. The first of these is the passenger pigeon, a species which 100 years ago was found in the eastern United States in incredible millions but which in the last 50 years decreased to total extinction. The last known living individual died September 1, 1914, in the Zoological Park at Cincinnati where it had been in captivity 29 years. The species is now believed extinct. It is barely possible a few individuals remain in some of our more remote heavy forests, but this is highly improbable. If, perchance, any should remain, they will receive absolute protection under the migratory-bird treaty act, and in time the species may be reestablished.

The band-tailed pigeon, a related species, is not rare in several of the Pacific Coast states. It will receive absolute protection for 10 years. At the end of that period, this interesting and beautiful game bird will doubtless be abundant again.

Still another related species is our common turtle dove, a species of wide distribution, common nearly everywhere, but abundant in nearly all our western states. The turtle dove is very tolerant of civilization and thrives well on the farms. To maintain it in safe numbers it is only necessary to have not too long an open season, a bag limit not too large, and to give rigid protection to their nests and eggs.

Very unfortunately, that great group of gallinaceous birds, the wild turkeys, quail, pheasants, grouse, ptarmigan, prairie chickens and sage hens, are not to be classed as migratory birds and therefore do not come under the protection of the migratory-bird treaty. There are about 50 species and subspecies of them, among which are some of the greatest game birds in the world. Many of them occurred in incredible numbers in the early days, while now probably not one is found in anything like its original abundance.

The wild turkey was doubtless the greatest game bird the world has even known. Up to the close of the Civil War this wonderful bird was abundant from Maryland westward to Minnesota and eastern Kansas and south to Florida and Texas and through New Mexico into Arizona. In the Upper Mississippi Valley it was common in all suitable places as late as 1870; in a few favored localities small flocks survived into the early eighties. In certain localities in southern Missouri, Oklahoma, Texas and Florida a few remain to this day; and it is said a few may be seen in Virginia within sight of the dome of the Capitol at Washington. In New Mexico and Arizona considerable numbers still remain.

The nature of the wild turkey is such as apparently makes it intolerant of civilization; it is not necessarily so. While it is a bird that under persecution requires heavy cover, it thrives well in open woods, especially of oak and beech if not too persistently molested. There still remain in many of the states thousands of acres of excellent cover where the species could doubtless maintain itself if once reestablished and proper protective laws and regulations provided.

What I have said regarding the wild turkey can be said of most of the species of gallinaceous birds. Most of them were once vastly more abundant than they now are and many of them must be classed among the vanishing game birds unless something is done soon for their preservation. The ruffed grouse and all the quail,

the prairie chicken and the sage hen, are each, in varying degrees, seriously depleted and in danger of actual extermination. While much has already been done to save the bob-white and other quail, and perhaps a few others, even they are doomed unless a great deal more is done.

The natural cover along the stream courses, on the hillsides, in the glens and dells and in and about the marshes and swamps affords ideal environment for the ruffed grouse. Every effort should be made not only to preserve every existing acre of this cover, but the cover should be improved whenever possible, and new acreage should be added from time to time by encouraging wild growth upon otherwise useless land. On many farms there are small waste areas which, with a little carefully directed neglect, can be converted into copses that would serve admirably for birds of this kind.

Cover that is good for ruffed grouse is also good for the bob-white. Even a very small thicket will furnish ideal cover for a flock of bob-whites. A number of such thickets judiciously located about the farm would do wonders in keeping it well supplied with these birds.

The prairie chicken, like the bob-white, is a species tolerant of civilization. Fields of grain such as wheat and corn are just to their liking and the wastage in the fields would assure an abundant food supply throughout the winter and any periods of food scarcity that might come. All that is necessary is a few waste places on the farm covered with copsy thickets and tall grass.

Of course their nests must be protected; and this leads me to make a plea for the unkempt fence corner, where the grass and weeds are allowed to grow and the briars and brush to run riot over the ground and fence. True, this is not so possible now with our wire fences as it was in the good old days of the picturesque old Virginia stake-and-rider rail fence—more's the pity. Such cover as the fence rows of this kind would afford would prove invaluable to prairie chickens and quail by supplying protection not only to the birds themselves but also to their nests.

The sage hen is one of our most picturesque and most valuable game birds. In size it is inferior only to the wild turkey. On our western sage-brush plains it formerly occurred in countless numbers. Its natural habitat was the almost valueless sage-brush country where agriculture is in most places impossible, although it has a slight value for grazing. And it is this that is exterminating the sage hen. Flocks of sheep ranging over the sage-brush plains during the breeding season of the sage hen are almost certain to destroy every nest which the sheep herders had not already robbed. Regions in which sage hens were common only a few years ago are

now without a single bird. Unless the Federal government and the states take action very soon the sage hen is doomed.

The woodcock is another of our splendid but vanishing game birds. Perhaps no other game bird has been more highly esteemed. Feeding, as it does, almost entirely on angleworms and other food which it obtains by prodding in the soft ground of the borders of ponds, springs and marshes, it is easy to see how disastrous to this bird the draining of our marshlands must inevitably prove to be. Moreover, it is a delicate bird, easily influenced by sudden freezes which make it difficult for it to obtain food.

Much can be done toward saving the woodcock by leaving undrained all marshland, ponds and springy hillsides that are not really needed for agricultural purposes.

The jacksnipe is very similar to the woodcock in its habits, game qualities and danger of extermination, and the measures that would be taken to save the one would apply to the other.

Of the scores of species of our less important game birds I need say little, except that they must not be forgotten and that measures taken to conserve the important species will ordinarily apply to the less important ones as well.

Game Mammals

Excepting perhaps Africa, no other country in the world ever equaled North America in the richness of its game mammals, marvelously rich not only in species and subspecies but also in number of individuals. Of the more than 300 species that might be mentioned, it must suffice to speak of only a few, for the story of former marvelous abundance, wasteful killing without thought for the future, and inevitable extermination or serious depletion applies to all.

The three species of grizzly bears that occupied such a picturesque place in the early history of California are all extinct; it is believed that not a single individual remains alive anywhere to-day. Many of the others, while not actually extinct as species, have been actually exterminated over a large portion of the country over which they originally ranged. Among these are several species of deer, the buffalo, moose, elk, antelope, various bears, foxes and gray squirrels. All that we have left now are isolated pitiful remnants of the vast numbers with which our older people were once so familiar. Many of them are so rare now that we can truthfully say they are, indeed, commercially extinct, and can never be restored.

Of course, it is quite true that serious depletion, even commercial extinction, of some of these species, such as the buffalo, was inevitable. On the other hand, it ought to be possible to reestab-

lish many of these species and bring them back to something like their former abundance. The changes in environment incident to the development of the country agriculturally and otherwise should not necessarily prove fatal to them. Moose, deer, bear, foxes, squirrels, beaver and muskrats could doubtless be maintained indefinitely in large numbers in many parts of their original habitat, if given that protection which can easily be given, and at the same time splendid productive hunting could be had. This would apply to Maine, the Adirondacks and other parts of New York, many parts of Pennsylvania, Michigan, Wisconsin and Minnesota. And the same could no doubt be done in all the states along our northern boundary and in all the Pacific Coast states. The muskrat should still find a congenial home in all parts of the United States east of the Sierras wherever swamp land, marshes, permanent ponds and small lakes are found; provided, always, that such of these favorable localities as can not be made agriculturally valuable are left undisturbed.

It is true that some of our most interesting game animals are predatory, not only upon other wild animals such as deer, antelope, elk and ground-nesting birds, but also are destructive to domestic stock. Among the worst are the wolves, coyotes, Canada lynxes and mountain lions. The United States Bureau of Biological Survey has been waging a very effective campaign against these predatory animals. When the Bureau began its campaign a few years ago it was estimated that these animals were causing a loss of more than $20,000,000 annually. Expert hunters and trappers were employed by the Bureau in cooperation with the states and with other interested agencies with the result that more than 50,000 predatory animals were destroyed in one year. If these animals had not been killed they would have destroyed fully $3,000,000 worth of domestic live stock to say nothing of the great numbers of deer and other valuable game mammals and birds they would have destroyed.

One sheep man wrote to the Survey that its predatory-animal hunters had saved his flocks from the loss of at least 1,000 lambs in one year. There are among predatory animals just as there are among dogs individuals that have acquired the sheep-killing or calf-killing habit, and the expert hunters make special and usually successful efforts to get them. A noted case was that of the notorious Custer wolf in Wyoming, which was believed to have killed $25,000 worth of cattle in a period of seven years. So crafty was this old wolf that he eluded all efforts to capture or kill him in spite of the fact that a bounty of $500 was placed on his head. But last year he met his fate through the skill and marksmanship of a bureau hunter.

Another illustration: a pack of eight wolves that had inflicted losses totaling $20,000 on calves, pigs and sheep about the Arkansas National Forest were all destroyed by a single bureau hunter in a period of three weeks. Still another old renegade wolf reported to have destroyed $6,000 worth of cattle on a single ranch besides making heavy inroads on other ranches, including nine head of yearling cattle in the last six weeks of his life, finally fell a victim to a skillfully placed trap of a bureau hunter.

The California Fish and Game Commission estimates that a mountain lion will kill on an average one deer a week throughout the year, and that there are about 600 lions in the state. At 52 deer each they would kill about 30,000 deer annually, which is about twice the number killed by all hunters in the state. From this it appears that the mountain lion should receive no protection.

Fortunately, the great majority of our important game mammals are not predaceous at all, or in only a slight degree. Fortunately also, some of the species are being conserved fairly well in some parts of their range. This is especially true of the deer.

The federal and state governments have established a number of game preserves, some of them under fence. The principal game animals in these reservations are buffalo, elk and antelope. All are showing satisfactory increase each year, and there is every reason to believe that these herds will continue to thrive.

The outlook for the wild elk, antelope, mountain sheep and mountain goats is not so encouraging.

Of the several species of elk the one commonly known as the California Valley elk or Tule elk is in most serious danger of extermination. This species formerly ranged over the San Joaquin Valley in great numbers. About 50 years ago it was threatened with extermination, but it was saved through the active interest of Henry Miller, head of the great cattle company of Miller & Lux.

In 1914 the only remaining herd of this species ranged over the Buttonwillow ranch of Miller & Lux in Kern County. In that year and in 1915 the California Academy of Sciences with the cooperation of Miller & Lux distributed 150 of these elk to various federal, state and private parks in the state, and it is gratifying to know that in most cases the animals have increased in numbers, and that these nuclei of new herds are doing well.

But the original herd in Kern County is in serious danger. Although it is unlawful to kill any elk in California, the warden service is poor and the animals are not receiving the protection they must have if the herd is to be saved. In my judgment the species is doomed unless more adequate measures for their protection be taken soon.

Probably the best thing to do would be to enclose with suitable

fence not less than 3 or 4 square miles of land in the region they inhabit. It would be easy to do this. A strip of land one mile wide, beginning up toward the foothills where the elk habitually stay and extending down into the valley about four miles so as to include about 300 acres of arable land on which alfalfa can be grown to supply feed in the dry season, is all that is necessary. The sale of surplus males and other animals from time to time to zoological parks, etc., would render the herd self-supporting.

Fur-Bearing Animals

Few of us realize what an asset the various states have in their fur-bearing animals. America's list of fur-bearers is a long one; the total number of species and subspecies whose pelts have considerable commercial value as fur is not fewer than one hundred. Among those of most importance may be mentioned the beaver, otter, fisher, mink, fur seal, sea otter, marten, muskrat, skunk, raccoon, weasel, fox, lynx, bobcat, wolf, coyote, and bear. Several of these are represented in the United States by two or more species or subspecies.

Not until recently were several of these species in much demand, but now the lowly muskrat and the much-despised skunk have come into their own. They are now among the most popular and high-priced furs.

As Dr. Dearborn, of the Bureau of Biological Survey, has well said, the demand for fur has existed since primitive man first sought skins to shield his naked body from the cold. This demand is fundamental and will endure while man inhabits the earth and furs are to be had. Its strength can be judged by the volume of trade it supports.

The fact that many of the fur-bearers are predaceous animals complicates the problem. However valuable the fur of an animal may be, if the habits of that animal be such as render it an enemy of domestic stock or useful game animals, its conservation is not an unmixed blessing. Such animals must therefore receive special treatment. Fortunately, the majority of our fur-bearers are destructive to other useful species or interests only in a small degree or not at all, and it is possible to provide laws and regulations for the conservation and proper utilization that will render their preservation highly desirable.

Some of the more important species are already seriously depleted; some have been even exterminated in many regions where they were formerly abundant. The beaver, marten and mink may be mentioned as examples of this class. Their extermination has been brought about chiefly by excessive trapping and changes in the character of their environment. It is believed that most of

those which have been greatly depleted can be restored and maintained in reasonable abundance if proper laws and regulations be provided for their protection.

The essential principles of the protection of fur-bearing animals are few and easily understood. In the first place, there should be a permanent closed season for a period of years in any region in which the species has become so seriously depleted as to be in danger of extermination. In the second place, no animal should be killed during the breeding season; that is, when its death would mean the starvation of the young; and fur-bearing animals should be killed only when their fur is prime.

Perhaps the most important of these is that relating to unprime skins. It has been estimated that the value of the furs that come to the markets is reduced fully 25 per cent. by the large number of unprime skins. Killing fur-bearers in their breeding season before the family break-up and dispersal in the fall is a wasteful practice. Uniform laws throughout the United States prohibiting traffic in unprime skins should be enacted.

Every trapper or hunter of fur-bearing animals should be required to secure a license good for one year, and he should be required to report at the end of the season the number of animals of each species taken. This would furnish data essential to determining the value and extent of the fur resources of the state and the relative abundance of the different species. Such statistics would inspire people with a desire and determination to make fur a regular and valuable farm and forest crop.

Under natural conditions or such as can be easily maintained, one or more species of fur bearers may be found in some numbers on many of the farms of the country. Hunting or trapping such animals is a recreation, sport or avocation that appeals strongly to most country boys. If they do their trapping intelligently, they will not only profit greatly by the sport it affords but will also add materially to the income from the farm.

Fur-Farming

Recently the possibilities of fur-farming have begun to attract wide attention.

Figures compiled by the Bureau of Biological Survey show that there are fur farms in at least 25 states. There are about 500 ranchers raising silver foxes, with 12,000 to 15,000 foxes in captivity.

Other species on the fur-farms are skunk, raccoon, mink, opossum, marten, muskrat, squirrel and beaver. The business, when intelligently conducted, is a fascinating and profitable one and can be carried on successfully in almost any of the states.

The state agricultural colleges and experiment stations, and state game and conservation commissions should encourage fur-farming. The United States Bureau of Biological Survey will be glad to give directions and suggestions as to the methods of fur-farming that one must follow to insure success.

In those parts of the country where there are small lakes or ponds surrounded by marshland opportunities for fur-farming are excellent. Usually in each marsh there will be found from a few to many muskrats. With proper care and management, the number can usually be greatly increased and maintained, at the same time permitting a considerable annual catch. And now that the muskrat is so popular as a fur, under the trade name of "Paris Seal," muskrat farming will prove a very profitable side issue on the farm.

Marine Mammals

There remains one important natural resource in which this country is vitally interested, the conservation of which has received practically no attention; and this appears all the more astonishing when we realize that in this natural resource are found not only the largest animals in the world but a number of the most valuable. I refer to the marine mammals—the whales, fur seals, walrus, sea lions, sea otters, porpoises, the elephant seal and other species whose home is in the sea. And it is a curious fact that we know less about these great and interesting animals of the sea than we do of any other group of useful animals.

We know a good deal about the Alaska fur seal; a little is known about the Russian fur seal and the Japanese fur seal, but scarcely anything about the several species in southern waters.

Some years ago, a species of fur seal was not uncommon about the islands off the coast of California and Lower California. In the early part of the last century it was very abundant on the Farallons just off the Golden Gate. One party that visited those islands in 1808 took in two seasons 130,000 fur seals and many sea otters. Another party took 33,740 fur seals in 1810 and 39,555 in 1811. The catch in four years was more than 200,000. It has been thought this species became extinct about 30 years ago. However, the capture of a living specimen in March (1922) near San Diego shows that it is not yet extinct; it further emphasizes our lack of knowledge of the distribution and abundance of our marine mammals. It also suggests the possibility of reestablishing fur-seal rookeries on the Farallons and other islands off the coast of California and Mexico. What a fine achievement that would be!

We know only in a general way what species of marine mammals there really are in the North Pacific; but it is safe to say the mammalian fauna of the Pacific is the richest in the world. There

are probably not fewer than 50 species in the North Pacific and the total number in the entire Pacific is doubtless much greater; but we do not really know. In the North Pacific we may recognize 14 kinds of whales, 12 porpoises, killers, dolphins, etc., one bear, two sea otters, four fur seals, and a dozen hair seals, harbor seals and sea lions.

With few exceptions practically nothing is definitely and authoritatively known of the life history of these animals. Their food and feeding habits, distribution, migrations, breeding seasons and places—these are but a few of the many things in the life history of these species about which we would like to know and which we must know before final measures for their protection can be intelligently formulated.

The commercial fisheries of the North Pacific can be properly understood and regulated only in the light of pretty full knowledge of the whales, seals and other marine mammals. We must know just what relation the whales, sea lions, harbor seals and porpoises sustain to the salmon, sardine, herring, cod and other food-fishes of our coast. The relation of the California sea lion to the salmon fisheries has long been a matter of dispute. Conclusive and convincing study of the question has never been made, and no one is in a position to say just what laws and regulations should be enacted regarding those species. The same is true of the whales. Our knowledge of their abundance, distribution and feeding habits is very incomplete.

Not long ago the Moss Landing Whaling Station of the California Sea Products Company reported they had found in the stomach of one humpback whale 1,500 to 3,000 pounds of sardines, besides a miscellaneous lot of smelt, anchovies, shrimp and squid! In the stomach of a sperm whale were found a 10-foot shark, a piece of fur-seal skin and a bunch of fishhooks! Some time ago two killer-whales or Orcas were examined at the Pribilof Islands; the stomach of one contained 18 fur seals, the other 24. At current prices of fur-seal skins those meals cost about $1,000 to $1,500 each!

These illustrations are sufficient to show that these species bear a very important relation to the sardine, fur seal and other commercial fisheries. And they further show the necessity of a thorough study of the relation of these and other marine mammals to the fisheries.

The Moss Landing Whaling Station furnishes exceptional facilities for a study of the whales. The California Sea Products Company which owns and operates this station has very kindly kept certain records, at the writer's suggestion, during the past four years. These records include the following data for each

whale taken: species, sex, length, weight, stomach contents, date when taken, place where taken, and size of embryo, if any.

The total number of whales taken by this company on the coast of California from January 16, 1919, to May 3, 1922, was 832. Seven different species were represented, as follows: bottlenose 1, sei 1, California gray 1, sperm 5, sulphur-bottom 5, finback 33, and humpback 781; total 832.

These figures are of value in that they show the species of whales that now occur on the coast of California and the relative abundance of the different species. It is seen that only one—the humpback—is at all common. The scarcity of the others is significant; indeed, all but the humpback are already commercially extinct. Only the humpback remains in sufficient abundance to justify the establishment of a whale fishery on this coast.

In 1853 Captain Scammon estimated that fully 30,000 California gray whales visited the California coast annually. The small catch of that species shows clearly that it has been almost exterminated on the California coast. It is evident that the humpback whale also will soon be as seriously depleted unless effective measures be taken soon for its protection.

While the whales are the largest animals in the Pacific, they are by no means the only ones that are in grave danger of extermination and that need protection.

In the early days the southern sea otter was common on the California coast and about the islands off the coast of Lower California. According to old Spanish records 9,729 sea otters had been taken on the California coast prior to 1790. The O'Cain expedition in 1803-4 took 1,100, the Winship expedition took 5,000 in 1805-6, and a party under a man named Campbell took 1,230, all on the California coast. From these figures it is evident that the sea otter was formerly very abundant on the California coast and that the environment was a very favorable one. It seems that it should be possible to reestablish the sea otter in those waters. While none has been seen for several years, there is good reason to believe a few still survive.

The Guadalupe fur seal was at one time common about certain islands off Lower California, but none was seen since 1892 until in March of this year, when one was captured near San Diego. This would indicate that there still exists a remnant of a herd that can again be built into one of commercial importance.

Up to a few years ago the great elephant seal existed in considerable numbers at Guadalupe Island off Lower California. It is now almost extinct; only prompt action can save it. On the same coast and in the Gulf of California sea turtles were very abundant not long ago; now they are said to be very rare.

Several other species threatened with early extermination could be named, but these must suffice.

The Alaskan, Russian and Japanese fur-seal herds are now fairly safe, thanks to the International Fur-seal Treaty entered into in 1911 by the United States, Great Britain, Russia and Japan. The northern sea otter is also protected by the same treaty. While that treaty has some serious defects it is believed they can be corrected in 1926 when an opportunity to do so will be afforded. But this treaty, unfortunately, does not cover whales, walrus, sea lions, southern sea otter, elephant seal or any of the southern fur seals.

It is perfectly lawful for anybody to kill any of these animals anywhere on the high seas. No country has jurisdiction beyond the 3-mile limit. Only by international agreement can they receive the protection necessary for their preservation and conservation.

The United States should take the initiative in bringing about an international treaty for the protection of the marine mammals of the Pacific. The principal countries concerned are the United States, Japan, China, Russia, Great Britain, Mexico and Chile, but every country at all interested in the Pacific should be invited to join in the treaty.

At the meeting of this association held in Berkeley last year a "Committee on the Conservation of Marine Life of the Pacific" was appointed. This committee is now functioning under the Committee on Pacific Investigations of the Division of Foreign Relations of the National Research Council. The committee is endeavoring to develop an interest on the part of the public in conservation of our natural resources, particularly those of the sea. It is endeavoring to interest the zoologists of the countries bordering on the Pacific in the wonderful animal life of that great ocean. It is making investigations and assembling data regarding the former abundance of various species, their present condition, and the causes which brought about the change.

In its efforts toward creating a strong public sentiment for conservation, the committee is trying to interest boards of trade, chambers of commerce, fish commissions, scientific societies, newspapers, women's clubs, and officials of educational institutions including colleges, normal schools, and public schools. It hopes to make use of the public press and public lectures that the people may learn something about the wonderful resources of the sea which we, through ignorance, indifference and greed, are permitting to be seriously if not fatally depleted. The committee plans to form an association or organization to be known by some such name as "The Associated Societies for the Conservation of Marine Life of the Pacific," and it is hoped to bring into this association as many as possible of the naturalists, educational institutions,

chambers of commerce, boards of trade, fish and game commissions, fishery companies and other interested units found in the various countries bordering on the Pacific.

It is hoped that public interest in the conservation problem of the Pacific will in the near future be developed to such an extent as will result in an international treaty broad enough in its scope to cover not only all the marine mammals but also the fishes, birds, and reptiles of the Pacific Ocean.

That our game mammals and birds, our fur-bearing animals and our marine mammals are among our most valuable natural resources is not fully realized by many of us. A few figures, however, will readily convince us that we have in these animals natural resources almost fabulous in their money value. Take for example the deer: the number of deer killed in 1915 by hunters in 36 states was 75,000. At 150 pounds each these would weigh 11,250,000 pounds, worth 20 cents a pound, or $2,250,000. It is claimed that the annual kill of deer in the entire United States could safely be put at 100,000, worth $3,000.000. Rabbits are a very valuable food asset. In 1918, 465,000 were killed in the State of New York alone. In 1919, 2,719,879 were killed in Pennsylvania. In 1920, 293,665 were killed in Virginia. At 20 cents apiece (a very conservative estimate) these rabbits had a money value of $695,710, which is no small item in the food supply of the country. And this embraces the catch in only three states. In the whole United States it must have been many times as great.

Now let us consider the game birds. In 1920 hunters in Minnesota killed 2,083,991 ducks, geese and other game birds, worth at least $1,000,000. In the same year there were killed in Virginia 187,582 quail, pheasants, turkeys, doves and woodcock worth more than $110,000. The take of game animals in the same period was valued at $350,000, while in New York the game mammals and birds taken in the same period numbered 1,526,960 valued at $3,239,277. From these figures it is believed that the game mammals, fur-bearing animals, and game birds of the United States yield to our people not less than the stupendous amount of $100,000,000 annually. Surely the conservation of such valuable resources as these is well worth while.

I should like to say something about the fisheries and the fur seal, those wonderful resources in which I have been most interested for many years, but time does not permit.

I can only say that they, too, must receive our most thoughtful and serious consideration if they are to be rehabilitated and maintained in anything like their former productiveness. No nation can grow populous and great and long survive which, through lack of vision, continues to destroy those very resources which have made it great.

SOME THOUGHTS ON IMMIGRATION RESTRICTION

By Professor ROBERT DeC. WARD
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A survey of American literature on immigration during the past twenty-five years emphasizes certain general tendencies. There has been a singular failure on the part of many writers to appreciate the larger, more fundamental, more permanent relations of the problem. The immediate, the temporary, the individual aspects have been unduly emphasized. There have, of course, been outstanding exceptions to this broad statement: men of vision, who have labored earnestly to bring before their fellow-countrymen the far-reaching racial, economic, political and social relations of alien immigration. But, in the main, most of what has been written has not been constructive in the best sense of that term. In view of the present widespread discussion of immigration in our magazines, in Congress and in our daily newspapers, the writer of the present article has thought it worth while to consider briefly some of these larger aspects of the problem as they present themselves to his mind. There is danger that the public will be diverted from a really serious consideration of the question as a whole by having its attention constantly directed to the stories of individual hardship—mostly fictitious or exaggerated—which are being so assiduously fed to the daily press by influences which are opposed to all restriction.

America's "Traditional" Immigration Policy

In any discussion of immigration problems reference is sure to be made to our so-called "traditional policy" of providing an asylum and a haven of refuge for the poor and the oppressed of every land. There is a fundamental error in the popular conception of this "tradition."

The desire that there should be some restriction has existed from the very foundation of our Republic. Washington questioned the advisability of immigration except of certain skilled mechanics. Jefferson expressed the wish that there were an ocean of fire between this country and Europe, so that it might be impossible for any more immigrants to come here. The Hartford Convention, in 1812, proclaimed that "the stock population of these states is

amply sufficient to render this nation in due time sufficiently great and powerful.'' In spite of these early distinctly restrictionist views, it was, nevertheless, for generations a national ideal that America should be an asylum and a refuge. But it must be remembered that immigration was then welcomed and encouraged because it was regarded as a source of national strength. The noble ideal of a refuge, open to all, had its roots in economic conditions far more than in any generous spirit of world philanthropy. The country was very sparsely settled. There was an abundance of free land. Labor was scarce. The number of immigrants was small. Nearly all of them were sturdy pioneers, of essentially homogeneous and readily assimilated stocks.

In time this ideal inevitably came into conflict with changing economic and social conditions. In the face of cold, hard, present-day facts it has had to be abandoned. These facts are that the supply of public lands is exhausted; that acute labor problems have arisen; that immigration has increased enormously and fundamentally changed its character; that our cities are congested with aliens; that we have failed to assimilate them, and that large numbers of mentally and physically unfit have come to our shores. Our so-called traditional policy began, in fact, to be abandoned almost fifty years ago, when Congress first put up the bars against certain classes of economically and morally undesirable aliens. It is now obvious that our ''asylum'' has become crowded with alien insane and alien feeble-minded; that our ''refuge'' is a penitentiary well filled with alien paupers and criminals.

The un-American policy is not restriction but indiscriminate hospitality to immigrants. It is un-American for us to permit any such influx of alien immigrants as will make the process of assimilation and amalgamation of our foreign population any more difficult than it already is. It is for the best interests of the alien as well as of America that our immigrants should be numerically restricted and wisely and carefully selected.

Our policy of admitting freely practically all who have wished to come has not only complicated our own problems, but has not helped the introduction of political, social, economic and educational reforms abroad. Our idealists tell us that the ''cream'' and the ''pick'' of Europe has been coming here because it is discontented at home; because it wants political and religious and economic liberty; because it wants education, and better living conditions, and democratic institutions. Have we in any way really helped the progress of these reforms by keeping the safety-valve of practically unlimited immigration open? By allowing the discontented millions of Europe and of Asia to come here now, are we

likely to hasten, or to delay, the coming of political and social reforms in Armenia, in Russia, in Turkey? Our duty as Americans, interested in the world-wide progress of education, of religious liberty, of democratic institutions, is not only to preserve our own institutions intact, but also to help the discontented millions of Europe and of Asia to shoulder their own responsibilities at home; to work out there, for themselves, what our own forefathers worked out here, for us and for our children. Are men and women who are now leaving their own countries and their own problems behind, likely to be of any real assistance to us in the maintenance and development of American institutions?

Fallacies of the "Melting-Pot" Idea

"Never shall ye make the crab walk straight. Never shall ye make the sea urchin smooth." Thus, many centuries ago, Aristophanes set forth his view of the fallacy of the "Melting Pot." We have been proceeding on the theory that the United States could, in the great American melting pot, crystallize into a new, homogeneous race, better and finer than has ever been known, the millions of aliens, of all nations, habits and languages, who have flocked to us from every quarter of the globe. We have thought that sending the alien children to school, teaching them English, giving them flag drills, and letting them recite the Gettysburg Address and read the Declaration of Independence, would make Americans of them almost overnight. Yet the laws which rule in the world of the lower animals obtain equally in the case of man. We can not make a heavy draught-horse into a trotter by keeping him in a racing stable. Nor can we make a race true to the old American type by any process of Americanization, essential as that undertaking is for creating better citizenship. It is distinctly the trend of modern biological discovery that heredity is, on the whole, far more important than environment in determining not only the physical but also the mental characteristics of man. Dr. Henry Fairfield Osborn, in an address before the recent International Eugenics Congress said: "We are slowly awakening to the consciousness that education and environment do not fundamentally alter racial values. . . . The true spirit of American democracy, that all men are born with equal rights and duties, has been confused with the political sophistry that all men are born with equal character and ability to govern themselves and others, and with the educational sophistry that education and environment will offset the handicap of ancestry."

What goes into the melting pot determines what shall come out of it. If we put into it sound, sturdy stock; akin to the pioneer breed which first peopled this country and founded its institutions;

if these new stocks are not only sound physically but alert mentally, then we shall develop a new race here, worthy to carry on the ideals and traditions of the founders of this country. But if the material fed into the melting pot is a polyglot assortment of nationalities, physically, mentally and morally below par, then there can be no hope of producing anything but an inferior race.

It is often said that each of the different alien peoples coming here has something to contribute to American civilization; that we shall be the gainers, not the losers, in the long run. That many of our immigrants have something to contribute is true. But we want desirable additions to, and not inferior substitutes for the good we already have. There is nothing in biological discovery or principles which would lead us to hope that only the virtues of the races which are going to make up the future American will survive, and the vices be eliminated. In fact, the vices and the undesirable qualities are just as likely to survive as the virtues. We have, of late years, not been getting the best of Europe.

The immigration question is usually discussed from its economic, its political, its industrial sides. Yet its racial aspects are infinitely more important. The character of the future American race is to be determined by the aliens who are landing on our shores day by day. As Dr. Lothrop Stoddard has stated the case, "the admission of aliens should, indeed, be regarded just as solemnly as the begetting of our own children, for the racial effect is essentially the same." And Major General Leonard Wood summed up the Melting Pot problem clearly and briefly when he said: "The American cement has about all the sand it will stand."

The statement of Aristophanes, above quoted, finds a parallel in the words of one of the best-known of modern writers on heredity, Professor Karl Pearson. "You can not change the leopard's spots, and you can not change bad stock to good. You may dilute it; spread it over a wide area, spoiling good stock, but until it ceases to multiply it will not cease to be."

Immigration and the Need of Labor

A stock argument against immigration restriction is the "need of labor." Many, if not most, of the evils which have resulted from the enormous and practically unselected immigration of the past twenty-five years have been due to the reckless greed for "cheap labor" on the part of large industrial, railroad and mining "interests" in this country. These "interests" have set pocket book above patriotism. They have been regardless of every consideration other than that of speeding-up their factories, their railroad construction and their mine output. To those who realize that cheap foreign labor is often so cheap that it is dear at any

price; that it is usually, in the long run, socially and politically very expensive; that a tremendously rapid development of our country is by no means altogether desirable, and that every immigrant is to play a part in the formation of the future American race, this matter of cheap alien labor presents wholly different aspects.

As Dr. Madison Grant has recently said, if the only object sought is a quick development of our country; if within a generation we want to exploit all our natural resources; to have huge industrial plants at every turn; to build railroads and highways paralleling and criss-crossing each other in a fine-meshed network, then it is doubtless true that a huge supply of cheap foreign labor will be needed. But is this "need of labor" any adequate reason for admitting aliens by the wholesale, without giving any thought to the question whether they are going to be intelligent, law-abiding, constructive citizens? Any industrial triumph; any phenomenal exploitation of our resources; any remarkable accomplishment in the development of transportation which can be achieved only by means of such labor, will eventually be paid for with a price which will involve political and racial disaster.

The vital question is not how fast can we possibly develop this country, but how best can we develop it. We have been assuming that we could safely admit as many immigrants as can be industrially assimilated; as can, somehow or other, scrape up a living here, or, failing that, can be supported by our charitable organizations. But the real questions are: how many can be politically assimilated; how many can be thoroughly Americanized; and what sort of contribution are they likely to make in the development of our future race? The need of more "hands" to do our labor has been dinned into our ears for decades. "Hands across the sea" are the cheapest, so we have been importing them. Let us not forget that we are importing not "hands" alone but bodies and hereditary tendencies also. It is of vital consequence that the quality of these human beings who come to us from other lands should be of the best, so that they shall not injure but improve our stock. Every day that passes witnesses the landing on our shores of aliens whose coming here is absolutely certain to result in a deterioration of the mental and physical standards of the American race of the future.

There are doubtless many who, like the present writer, are not employers of labor, nor daily wage-earners, nor economists, who may, nevertheless, have certain views on this matter which are entitled to consideration. To those who belong to this group the question arises whether any American industry which can not

prosper without a constant supply of cheap foreign labor is really worth preserving in a country which boasts of the high standards of living of its wage-earners and the high character of its citizenship. For any indispensable work which can be done by relatively low-grade and unintelligent men and women there would be a sufficient supply of labor from the natural increase of those who are already residents of this country. Somewhat higher wages would probably have to be paid in certain cases and for a while, but if the price were too high, American inventive ingenuity would very soon solve the difficulty by means of labor-saving machinery. If a "cheap" man becomes too expensive, machinery inevitably takes his place. It would doubtless be far better and safer for the United States to enter upon a period of slower industrial development, with a labor supply recruited from the loins of its own population and from a carefully sifted and limited foreign immigration, than to drive ahead at its previous speed, with its industrial development stimulated by means which will inevitably result in a lowering of our political and racial standards. Furthermore, it is generally agreed even among anti-restrictionists that the majority of aliens now coming in are unfitted, by training or temperament, for common labor.

The late General Francis A. Walker laid emphasis upon one point which deserves mention, again and again, when the argument is made that we need cheap labor to do certain disagreeable and degrading jobs. No job, said General Walker, is too cheap or too mean for a self-respecting man to do. In the early days all our work was done by Americans, and none of it was neglected on the ground that it was degrading. The same thing is true in many of our country districts to-day, wherever there are native Americans who depend on themselves to do the necessary daily task. It was not until ignorant and unskilled aliens began to come in in considerable numbers, and took up the lower grades of unskilled labor, that these jobs began to be considered beneath the dignity of self-respecting Americans.

Will Distribution of Immigrants Solve Our Difficulties?

Anti-restrictionists wilfully, and some restrictionists ignorantly, argue that a better distribution of our immigrants will solve our problem of assimilation. The difficulty, it is claimed, is not that there are too many aliens but that they do not go to the right places. Our arriving immigrants naturally flock to the large cities, where their compatriots are already congregated, and where rough construction work and odd jobs are more easily found. Much is said about the need of farm labor, yet even if many thousands of aliens were actually distributed where there is a lack of

farm laborers, the majority of them would not be effective. What our great farming districts need is highly intelligent labor, skilled in American farming methods, and able to manage modern agricultural machinery. Ignorant, unskilled, non-English-speaking foreigners, who know little beyond the use of a primitive hoe, are not wanted.

It is significant that at the last annual session of the Farmers' National Congress, with delegates from over thirty states in attendance, the following resolution was unanimously adopted:

> *Resolved*, That we are unalterably opposed to the proposed diversion and distribution of aliens over the farming districts until immigration is rigidly restricted, numerically or otherwise.

In a recent issue of the *Southern Textile Bulletin*, emphatic protest was made against the importation of foreign textile labor into the South. "We do not counsel violence," the paper says, "but if violence is necessary to rid our mills of these foreigners, it were better to have violence now than to see our operatives forced to live and work alongside a disreputable foreign element."

In his able and timely article, "Throwing away our Birthright," in the *North American Review* for February, 1922, Mr. William Roscoe Thayer states that "all attempts to distribute immigrants according to certain localities have thus far failed." The case is cited of a serious effort made some twenty years ago by the Italian Ambassador to the United States, Baron Mayor des Planches, to plant colonies of Italians in the Southern States. The scheme was unsuccessful. Two other specific instances of attempted distribution come to mind. One is the case of the importation of a shipload of picked immigrants by the State of South Carolina, every one of whom had disappeared within a few months. The other is that of the more recent importation of Mexican laborers into the Southwest during the war. These aliens were admitted under special conditions to do certain agricultural work, and were later to return to their own country. Most of these men also disappeared and could not be sent home again. In other words, while it may in certain cases be possible to distribute aliens, the matter of keeping them where they are sent is a wholly different matter. In the final analysis, on however large a scale it may be carried out, and however effective it may seem to be, distribution, as President Roosevelt put it in one of his messages to Congress, "is a palliative, not a cure." It can never solve our immigration problems.

SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE III. PART 2. BEES SOLITARY AND SOCIAL

The Meliponinæ, or stingless bees, are a very peculiar group of nearly 250 species, all confined to warm countries. Fully four fifths of the species occur only in the American tropics and only about one fifth in the Ethiopian, Indomalayan and Australian regions. All the Old World and the majority of the Neotropical forms belong to the genus Trigona; the remainder of the American species are placed in a separate genus, Melipona. The stingless bees are much less hairy and much smaller than the bumble-bees. Some of the species of Trigona measure less than 3 mm. in length and are therefore among the smallest of bees. The colonies vary greatly in population in different species. According to H. von Ihering, those of Melipona may comprise from 500 to 4,000, those of Trigona from 300 to 80,000 individuals. The name stingless as applied to these insects is not strictly accurate, because a vestigial sting is present. It is useless for defence, however, so that many of the species are quite harmless and are called "angelitos" by the Latin-Americans. But some forms are anything but little angels. When disturbed they swarm at the intruder, bury themselves in his hair, eye-brows and beard, if he has one, and buzz about with a peculiarly annoying, twisting movement. Others prefer to fly into the eyes, ears and nostrils, others have a *penchant* for crawling over the face and hands and feeding on the perspiration, or bite unpleasantly, and a few species spread a caustic secretion over the skin. On one occasion in Guatemala large patches of epidermis were thus burned off from my face by a small swarm of *Trigona flaveola.*

There are three morphologically distinct castes. The queen differs from the worker in the smaller head, much more voluminous abdomen, more abundant pilosity, and in the form of the hind legs, the tibiæ of which are reduced in width and furnished with bristles also on their external surfaces, while the metatarsi are elongate, rounded and apically narrowed. The worker, therefore, really represents the typical female of the species morphologically, except that she is sterile, whereas the queen, except in her ovaries,

exhibits a degeneration of the typical secondary characters of her sex. There is only one mother queen in a colony, but a number of young daughter queens are tolerated. New colonies are formed by swarming, that is, by single young queens leaving the colony from time to time, accompanied by detachments of workers, to found new nests. The body of the old queen is so obese and heavy with eggs and her wings are so weak that she can not leave the nest after it is once established.

The nests of the Meliponinæ are extremely diverse in structure. They are usually in hollow tree-trunks or branches, less frequently in walls. Some of the species nest in the ground, and a few (*T. kohli, fulviventris, crassipes, etc.,*) actually build in the centers

FIG. 46
Cerumen spout, or nest entrance of a large colony of *Trigona heideri* Friese nesting in a hollow tree at Kartabo, British Guiana. About 1/3 natural size
Photograph by Mr. John Tee Van.

of termite nests. The nest is made of wax, which most of the species mix with earth, resin or other substances, so that it is chocolate brown or black and is called "cerumen." The wax is secreted only between the dorsal segments of the abdomen, and is produced by the males as well as by the workers—the one case in which a male Hymenopteran seems to perform a useful social function. The workers not only collect nectar and pollen but they seem to have a greater propensity than other social bees for gathering propolis, resins and all kinds of gums and sticky plant-exudations. And unlike other bees they are also fond of visiting offal and the feces of animals. One species is said even to eat meat (*T. argentata,* according to Ducke).

The entrance to the nest may be a simple hole, but more often it is a projecting cerumen spout or funnel, which differs considerably in different species (Fig. 46). In some East Indian Trigonas its lips are kept covered with sticky propolis to prevent the ingress of ants and other intruders (Fig. 47*AB*). In most of the South American species its orifice is guarded during the day by

FIG. 47

Cerumen entrances to nests of Meliponine bees. *A.* Of *Trigona laeviceps* of India in profile; *B,* same seen from the front (After C. S. P. Parish); *C,* nest entrance of *Melipona quinquefasciata*; *D,* nest entrance of *Trigona limao* After F. Silvestri.

a special detachment of workers and is closed at night with a cerumen plate or screen. The interior of the nest presents a peculiar appearance. If it is in a hollow tree-trunk or branch the cavity is closed off at each end by a thick lump or plate of cerumen (the "batumen"). The nest proper (Figs. 48 and 49), constructed in the tubular space thus preempted, consists of two parts, one for the brood and one for the storage of various foods and building materials. The brood portion consists typically of a hollow spheroidal

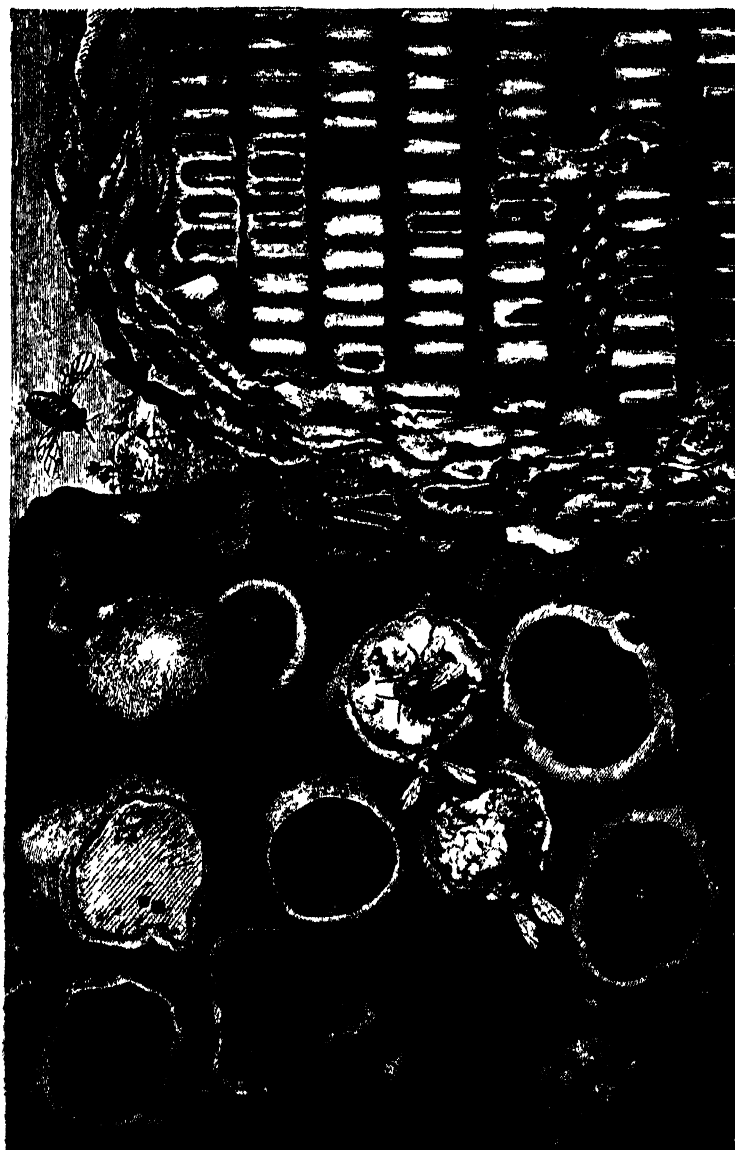

FIG 48

Portion of nest of *Melipona scutellaris*, showing brood-comb (to the right) and the large honey pot pollen pots (to the left). Subdiagrammatic drawing from Emile Blanchard.

FIG. 49
Nest of Melipona sp in hollow log, showing brood-comb (to the left), pollen pots and honey pots (to the right). Photograph by Dr. E F Phillips About one half natural size.

envelope of irregular, interconnected cerumen laminæ, forming the walls of an elaborate system of anastomosing passage-ways and enclosing a large central space occupied by a series of combs of hexagonal cells. There is only one layer of cells in each comb and they all open upwards, not downwards as in the social wasps. In some species the combs are regular and disc- or ring-shaped structures, in others they are arranged in a spiral or more irregularly. Their cells are used exclusively for rearing the brood. In Melipona and some species of Trigona they are all of the same size, but in several South American species of the latter genus single larger cells are constructed, especially towards the periphery of the combs, for the rearing of queen larvæ. All this elaborate arrangement would seem to be a preparation for a very specialized system of caring for the young, but such is not the case. The workers, precisely as if they were solitary bees, put a quantity of pollen and honey into each cell, and after the queen has laid an egg in it, provide it with a waxen cover, so that the larva is reared exactly like that of a solitary bee. There is mass but not progressive provisioning and the adult bees do not come in contact with the growing larvæ. The queen-cells are treated in the same manner, the only differ-

ence being that they are provided with a greater amount of pollen and honey. Among the species whose queen cells are no larger than those in which the workers and males are reared, the queens emerge with small ovaries and develop them later, but among the species which build large cells for the queens, the latter emerge with the ovaries fully developed. These differences are of considerable interest in connection with the queen honey-bee.

Outside the cerumen involucre enclosing the brood combs the workers construct large elliptical or spherical pots, some for the storage of honey, others for pollen and in some species still others

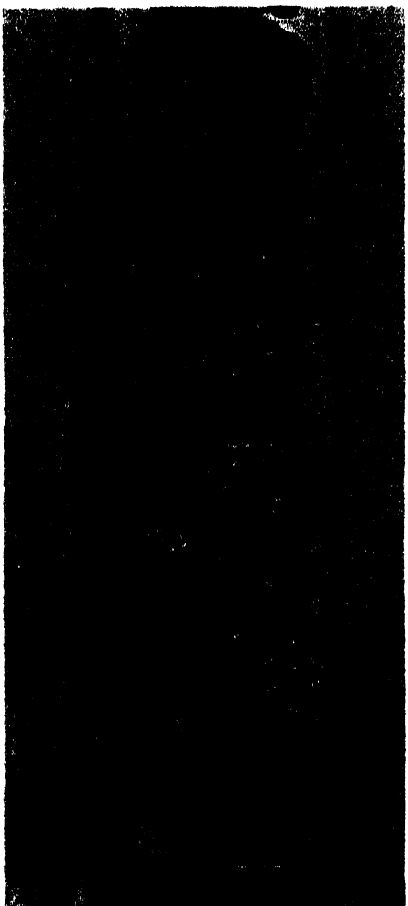

FIG. 50

Nest of a small Trigona (worker only 2.5 mm. long!) representing a new species near *T. goeldiana* Friese, in the hollow internodes of a small *Crecopia angulata* Bailey (sp. nov.) at Kartabo, British Guiana. *a*, brood-cells containing adult larvæ and pupæ; b, honey pots. Slightly enlarged. Photograph by Mr. John Tee Van.

for propolis. In one species (*T. silvestrii*) the pollen-pots are long and cylindrical while the honey-pots are small and spherical. This same arrangement is known to occur also in one of the European bumble-bees (*B. pomorum*). The Meliponinæ may also store other substances in the outer portions of their nests. In one nest of a black Trigona, which I observed at Kalacoon, in British Guiana, there were several lumps, each weighing 10 to 20 grams, of a hard substance closely resembling sealing wax in color and consistency. The species which build their nests freely on the branches of trees cover them with protective layers of cerumen arranged like those surrounding the brood combs.

The Old World Trigonas (*canifrons*, according to W. A. Schulz) and some of the South American species (*timida*, *silvestrii* and *cilipes*, according to Silvestri; *silvestrii* and *muelleri*, according to H. von Ihering; and a very small undescribed species allied to *T. goeldiana*, which I found in British Guiana, represent a more primitive stage in the construction of the nest (Fig. 50). The brood cells in these forms are elliptical and are not arranged in a comb but are isolated or loosely connected with one another by delicate waxen beams, or trabeculæ. They are therefore essentially like the cells of bumble-bees and solitary bees. It should be noted also that the Meliponinæ, like the bumble-bees, tear down their cells after they have been used and construct new ones in their places.

The rearing of the brood of all the castes in closed cells, after the manner of the solitary bees, is very significant, since it is the only case among the social Hymenoptera of a complete lack of contact between the adults and the larvæ. Even the bumble-bees open their cells from time to time and feed the older larvæ, and among the honey-bees the cells remain open throughout larval development. It is obvious that the Meliponinæ have either retained unaltered the ancient method of rearing the young in closed cells, employed by all the solitary bees, or have reverted to it after practicing a method more like that of the bumble-bees or honey-bees. As there seem to be no cogent reasons for adopting the latter alternative, I am inclined to believe that the former is the more probable and that unlike the wasps these highly social bees have never passed through a stage of actual trophallactic contact between mother and offspring. After considering the honey-bees I shall return to this question.

The Apinæ, or honey-bees, are separated by a wide gap from the Meliponinæ and Bombinæ and their origin is still wrapped in obscurity. Certain species, referred by their authors to the genus Apis, are recorded from the European Miocene (*A. adamitica*), Baltic Amber and Upper Oligocene (*A. meliponoides* and *hen-*

shawi). The genus as it exists to-day comprises only four species: *dorsata, florea, indica* and *mellifica,* the common honey-bee of our apiaries. *A. indica* and *mellifica* are so very similar in structure and habits and hybridize so readily that both Friese and von Buttel-Reepen have regarded the former as a mere race, or subspecies of the latter. Von Buttel-Reepen, however, has recently raised *indica* to specific rank on what seem to me to be rather dubious grounds. Inasmuch as *dorsata, florea* and *indica* are confined to the Indomalayan region, it has been usually assumed that *mellifica,* though now cosmopolitan, is also of South Asiatic origin. But von Buttel-Reepen believes that it had its origin in Germany and bases his opinion on the existence of the above-mentioned fossils in Germany and on the fact that the true *mellifica* did not exist in India till it was introduced by Europeans. The bee originally kept in that country by the natives was *indica.* The eminent melittologist's view is so startling that one is tempted to suppose that he, like some other German investigators, is the victim of a desire to make his fatherland the source of all good things. The following considerations seem to me to leave little ground for his opinion: First, if *mellifica* was not originally present in India it is probably because *indica* happens to be the South Asiatic race of the species. Second, the type of *mellifica,* that is, the form to which Linnaeus first gave the name, is, of course, the dark German, or northern race, and it is natural to regard the many local races and varieties in other parts of Europe, in Africa and Asia as mere modifications of the German type. But such a procedure is unwarranted in phylogeny, since the selection of the German race as the specific type was a mere taxonomic accident. Had a Hindoo entomologist preceded Linnaeus, *indica* would be the type of the species, and the Hindoo, aware of the existence of two other species of Apis in his and neighboring countries and nowhere else, would properly regard the genus as of South Asiatic origin and the species *indica* as having spread to Europe and Africa and as having produced among others a dark Germanic race. Third, it is by no means certain that the fossil forms, which have been described from imperfect specimens, really belong to Apis or that they are in the direct line of descent to that genus. And even if we admit this to be the case, it does not follow that they must have originated in Germany. Fourth, granting that a race of *mellifica* existed in that country during the Miocene, it must either have become extinct during the Ice Age or have been driven into Southern Europe. That this identical race and not a new one arising from southern forms later returned to Germany is a pure supposition. Fifth, the tropical origin of the honey-bee is indicated by its in-

ability to form new colonies except by swarming, precisely like the tropical Meliponinæ and Vespidæ. And while it is true that the climate of Central Europe during the Oligocene and Miocene was tropical or subtropical, the existence at the present time of at least three distinct species of Apis in the Indomalayan region and nowhere else makes it seem much more probable that the ancestors of *mellifica* emigrated from Asia into Europe than in the reverse direction, especially as Southern Asia is a well-known center from which many other animals have been distributed. The spread of the honey-bee throughout the world is evidently due to its extraordinary adaptability to the most diverse flowers and to a great range of temperature, to its habit of storing large quantities of honey and its ability to maintain a rather high temperature in the hive during periods of cold weather. This unusual plasticity is peculiar to the species and is not the result of domestication. The insect, in fact, has never been domesticated.

FIG. 51

Honey-bee (*Apis-mellifica*), *a*, worker; *b*, queen; *c*, male (drone). Twice natural size. After E. F. Phillips.

Like the Meliponinæ the species of Apis have three well-developed castes (Fig. 51). Normally there is only a single queen in the colony and she will not tolerate the presence even of another young queen. Swarming takes place by the old queen leaving the colony accompanied by a large detachment of workers when a young queen is about to emerge from her cell, and if several young queens are to emerge in succession, the older leaves before the next appears. It will be noticed that this is different from the swarming of the Meliponinæ, since in these bees the old queen remains in the nest and the young queens accompany the swarms of workers. When the queen's eggs are fertilized they develop into workers or queens according to the way the larvæ are fed, but when unfertilized into males or drones, as is also the case with the eggs that

are sometimes laid by workers. All the species of Apis make pendent combs of pure wax, which is secreted only by the workers and only between the ventral segments of the abdomen. The combs differ from those of the Meliponinæ and wasps in consisting of two layers of hexagonal cells, and the brood cells remain open throughout larval development, the young being fed progressively. The three species of Apis represent as many different phylogenetic stages, which may be briefly described.

A. dorsata is the largest and most primitive form (worker 16-18 mm.; queen 23 mm.; drone 15-16 mm.). It builds from the lower surface of a branch a single large semicircular comb, sometimes with a superficial area of a square meter. Its cells are regularly hexagonal and all alike. Part of them are used for storing honey, the remainder for the brood. In this species, therefore, the workers, queens and drones are all reared in cells of the same size and shape, like the species of Melipona and many Trigonas. *A. dorsata* is a nomadic bee, which builds its comb where flowers are abundant and after they have ceased to bloom deserts the structure and builds a new one in fresh pastures. Owing to this habit, all the attempts that have been made both in Europe and the United States to establish this bee in apiaries have failed.

A. florea is the smallest species in the genus (worker 7-8 mm.; queen 13-14 mm.; drone 12 mm.) and in certain respects represents an interesting transition between *dorsata* and *mellifica*. The drone is peculiar in having a finger-shaped process on the inner border of the hind metatarsus. Like *dorsata*, *florea* makes a single pendent comb, but it is much smaller and narrower and consists of four different kinds of cells. At the base where the comb surrounds the supporting branch the cells are hexagonal, large and deep and are used for storing honey. Below these there is a broad zone of small hexagonal cells for the worker brood and at the apical fourth still larger hexagonal cells for the drone brood. Finally, attached to the free border and depending like stalagtites there are several long conical cells for the queen larvæ.

A. mellifica and its subspecies *indica*, etc., differ from *dorsata* and *florea* in nesting in hollow cavities (tree-trunks, caverns, hives) and in constructing several pendent combs side by side, each presenting the types of cells seen in *florea*, except that there is no special type for storage, the honey being kept in cells like those used for rearing the worker brood. Moreover, the queen cells are never built on drone but only on worker comb. The singular shape of the queen cells (Fig. 52), so very different from the hexagonal cells, and the fact that they are the only cells torn down by the workers after being used, indicate that they are archaic

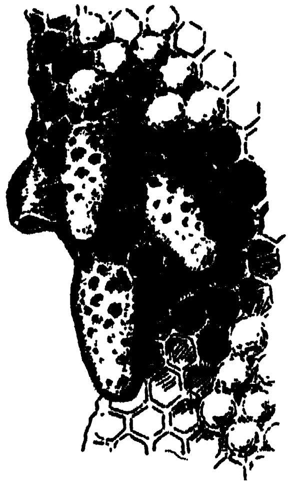

FIG. 52
Queen cells of the honey-bee Natural size. After E F Phillips

structures of considerable phylogenetic significance. They are, indeed, reminiscent of the only type of cell constructed by the bumble-bees. But owing to the fact that conical queen cells occur only in *A. florea* and *mellifica* and are the same in both species we are unable to advance any reasons for their retention among cells of the highly specialized hexagonal type. On rare occasions

FIG. 53
Comb built by a colony of honey-bees on the branches of a tree. From a specimen in the American Museum of Natural History by which this photograph and Fig. 54 were contributed.

a swarm of honey-bees, failing to find a hive or hollow tree-trunk, will construct its comb among the branches of trees or bushes. Such exposed nests have been described by Bouvier, and there is an unusually fine example in the American Museum of Natural History (Figs. 53 and 54). It will be noticed that in form each comb resembles the single comb of *A. dorsata* or *florea*.

Except in the development of her ovaries, the queen honey-bee is a degenerate female, a mere egg-laying machine, entirely dependent on her worker progeny. The pollen-collecting apparatus of the hind legs, so well developed in the worker and so charac-

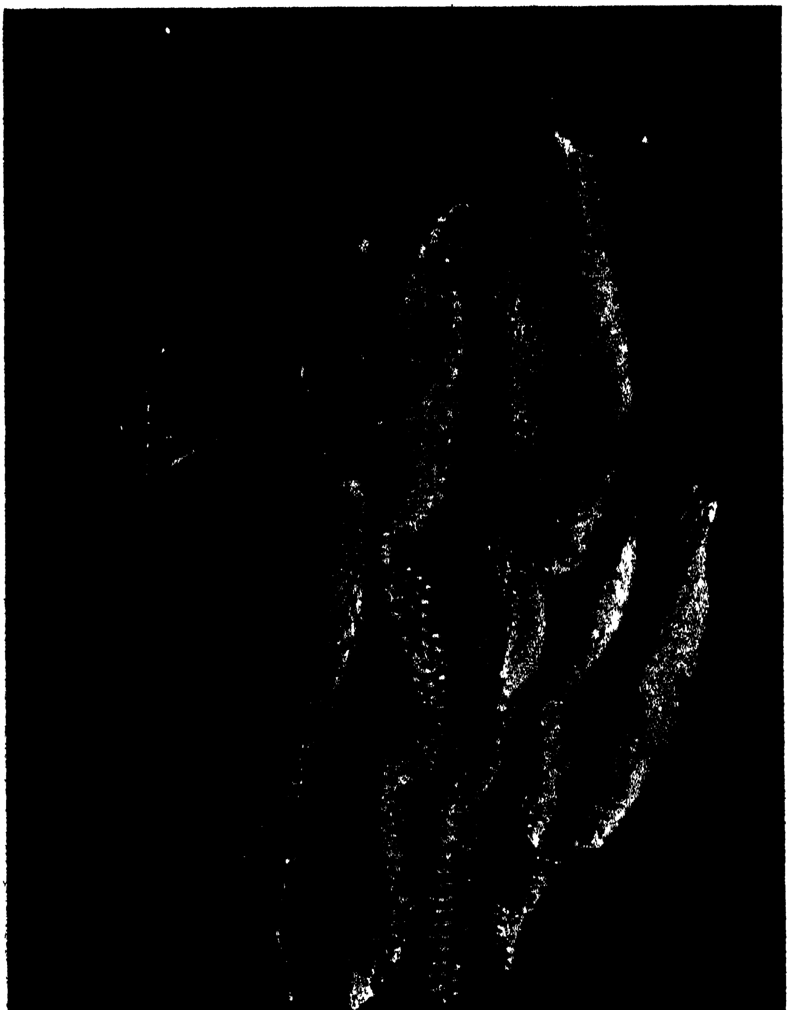

FIG. 54
Same comb as shown in Fig. 53, seen from the end.

teristic of the females of all non-parasitic, podilegous bees and of the queens of the bumble-bees, is undeveloped, her tongue and sting are shortened, her brain is smaller and she lacks the pharyngeal salivary glands of the worker. That these differences are due to larval feeding is proved by the experiment of transferring eggs and very young larvæ from worker to queen cells and *vice versa*. Transferring eggs from drone to worker or queen cells does not, however, alter the sex of the insect reared, since it develops from an unfertilized egg. Under normal conditions the time required for the development and the chemical composition of the food administered to the larvæ differ for the three castes. The difference in the rate of development is shown in the following table from von Buttel-Reepen:

DURATION OF DEVELOPMENT IN THE HONEY-BEE
(After von Buttel-Reepen)

DEVELOPMENT OF THE BROOD	QUEEN (DAYS)	WORKER (DAYS)	DRONE (DAYS)
Duration of egg (embryonic) development	3	3	3
Duration of larval development	6	6	6
Duration of spinning and resting period	2	4	7
Change of pupa to imago	5	8	8
Total	16	21	24

The composition of the food, which, for the queens and the earliest stages of the workers and drones, is a secretion ("royal jelly") of the pharyngeal glands of the worker nurses, is shown in von Planta's table taken from the same author:

COMPOSITION OF LARVAL FOODS OF THE HONEY-BEE
(After von Planta)

PERCENTAGES OF DRIED SUBSTANCE	QUEEN LARVÆ (AVERAGE)	DRONE LARVÆ UNDER 4 DAYS	DRONE LARVÆ OVER 4 DAYS	DRONE LARVÆ AVERAGE	WORKER LARVÆ UNDER 4 DAYS	WORKER LARVÆ OVER 4 DAYS	WORKER LARVÆ AVERAGE
Proteid	43.14	55.91	31.67	43.79	53.38	27.87	40.62
Fat	13.55	11.90	4.74	8.32	8.38	3.69	6.03
Sugar	20.39	9.57	38.49	24.03	18.09	44.93	31.51

We see from these tables that the queen, although the largest of the three castes, reaches maturity in about 16 days. She is fed only on "royal jelly," without admixture of honey or pollen. These highly nutritious rations (43.14 per cent. proteid) are undoubtedly responsible for her very rapid growth. The worker is given pollen and honey after the fourth day and requires 21 days to complete her development. The feeding of the drone is similar, but he receives less sugar and more fat and his development is protracted to 24 days.

The foregoing considerations suffice to show the complexity of the whole matter of sex-determination and caste-differentiation in

the honey-bee. There are libraries of contentious discussion of these subjects, which can not, of course, be adequately treated in a general lecture. Although all competent authorities agree that the drones arise from parthenogenetic or unfertilized eggs and the queens and workers from fertilized eggs, it is impossible, in the present state of our knowledge, to decide between two different theoretical interpretations of the facts. According to one, first stated by Dzierzon and more recently maintained by Weismann and his pupils and especially by von Buttel-Reepen, the queen lays only one kind of egg, which is potentially indifferent but has its sex determined at the moment of fertilization; according to the other, advocated by Beard, von Lenhossek and Oscar Schulze, there are really two different kinds of eggs, one of which does not need to be fertilized and develops into the drone, whereas the other requires fertilization to be viable and develops into a queen or a worker. Normally the queen lays unfertilized eggs only in the large drone cells and fertilized eggs only in the small worker cells and the peculiar conical queen cells. The hypothesis that the difference in the width of the cells is the stimulus which causes the queen to close or open the duct of her spermatheca and thus prevent or permit the exit of sperm while the egg is passing from the ovaries on its way to being laid, can not be accepted, because the queen often oviposits in cells which have had only their basal portion completed. Moreover, this hypothesis will not apply to the Meliponinæ, which rear males and workers in closed cells of the same size or to cases like those of the solitary wasps described in the preceding lecture and many solitary bees which regulate the size of the cell and the amount of provisions according to the sex of the offspring. These peculiar phenomena, first observed by Fabre in Osmia, Halictus and Chalicodoma, have been recently confirmed by Verhöff, Höppner and Armbruster. The observations show that the female bee must be aware of differences between her eggs sometime before she begins to lay them and certainly before there are any such stimuli as contact of her abdomen with the walls of the cell.

Referring to the Dzierzon theory, Phillips says: "The facts observed in the apiary on which this belief is based are as follows: (1) If a queen is unable to fly out to mate or is prevented from mating in some way she usually dies but if she does lay eggs, as she may, after three or four weeks, the eggs which develop are all males; (2) if when a queen becomes old her supply of spermatozoa is exhausted, her offspring are all males; (3) if a colony becomes queenless and remains so for a time, some of the workers may begin egg-laying and in this case too only males develop. The

author has found that many eggs laid by drone-laying queens fail to hatch and, in fact, are often removed in a short time by the workers. This makes it impossible for us to accept Dzierzon's statement that all eggs laid by such a queen become males and the statement must be modified as follows: all of those eggs laid by a drone-laying queen which develop become males. The potentialities of the eggs which never hatch are not known. In addition to the facts here stated, the theory of the parthenogenetic development of the drone is supported by investigation of the phenomena of development in the egg." He becomes more explicit in the following passage: "If we take into consideration the important fact that not all eggs of an unfertilized (drone-laying) queen hatch, then the bee does not appear as an exception in nature. It seems clear, however, that the statement of Dzierzon that all the eggs in the ovary are male eggs can not be accepted and it is, in fact, not improbable that the eggs destined to be females die for want of fertilization, while the eggs destined to be males, not requiring fertilization, are capable of development. It should be understood that the casting of doubt on Dzierzon's theory of sex determination does not invalidate his theory in so far as it pertains to the development of males from unfertilized eggs."

There are also several cases of hybridization that seem to indicate that Dzierzon's theory is only a partial or approximate interpretation. When a yellow Italian queen bee mates with a black German drone, the drone offspring, being fatherless, should of course be yellow like the mother, whereas the workers should combine the characters of both their parents. This is often the case, but although von Buttel-Reepen is a staunch supporter of Weismann and adheres rigidly to the Dzierzon theory, he is compelled to admit that occasionally "when an Italian queen is fecundated by a German drone, numerous blended hybrids ("Mischlinge") appear during the first year, but during the second year almost exclusively Italian, and in the third year exclusively Italian workers are produced, so that the population must be regarded as purely Italian." He has himself witnessed this phenomenon and states that it has also been observed by Dönhoff, Dzierzon and Cori. The only explanation von Buttel-Reepen has to offer is that the sperm, stored in the spermatheca of the queen, may in the course of time be increasingly affected by the secretions of her spermophilous glands, which keep the paternal elements alive during the three to five years of her life. The facts can hardly be explained on Mendelian principles even if we make all due allowance for the impurity of the German and Italian strains that produced the hybrids. It looks as if, at least under certain conditions, workers

might develop from unfertilized eggs. According to Onions, the workers of a South African race of honey-bees are able to produce workers parthenogenetically, and Reichenbach, Mrs. A. B. Comstock and Crawley find the same to be true of worker ants of the genus Lasius.

I believe that Phillips, in the remarks above quoted, suggests an important fact which has been too little noticed and may account for much misunderstanding in regard to sex determination in the honey-bee. Accurate knowledge of the life-history of a particular individual in a colony of social insects is almost or quite unattainable, for two reasons: first, the egg can not be isolated and the larva brought up by hand, like a young chick, because it requires the presence of nurses of its own species and they will not rear it under abnormal conditions; and second, the workers of many social insects are very fond of eating the eggs and young larvæ and these same workers or the queen not infrequently at once lay eggs in the place of those devoured. This behavior is especially common and disconcerting among the ants. Now a rigid control would require not only that the mother insect should be observed during the very act of oviposition but that the egg and resulting larva should be kept under constant observation day and night till the completion of development. A relay of observers, changing every few hours for two or three weeks, would therefore be needed in order to make sure that a particular adult had developed from a particular egg, and it would be necessary to observe many individuals in such a manner before we should have the data for accurate conclusions. In fact, we shall need all the resources of a specially equipped laboratory, with a specially trained staff, for any final solution of many of the peculiar developmental problems suggested by the honey-bee and other social insects.

Among these problems we should also have to include that of the differentiation of the two female castes, that is, the problem as to whether the worker and queen arise from one kind or from two different kinds of eggs. The experiments of transferring larvæ of different ages from worker to queen cells, as previously stated, and the existence of series of transitional forms between the worker and the queen, naturally lead to the view that there is only one kind of female egg and that the character of the larval food after the fourth day determines whether the adult is to be a worker or a queen. This may be true of the honey-bee, but, as we shall see, observations on certain ants and termites indicate that there may be more than one kind of female egg.

The main object of the rich and abundant food administered to the larva of the queen honey-bee is evidently the rapid develop-

ment of her ovaries, so that she may begin to lay eggs very soon after emergence. This is also indicated by the conditions in the Meliponinæ. The Melipona queen, which is reared in a closed cell of the same size as that of the workers and on the same amount of food, emerges with rudimentary ovaries and has to develop them by subsequent feeding during her adult instar, whereas the Trigona queen, which is reared in a large cell with more food than is given to the worker larvæ, emerges with mature or nearly mature eggs in her ovaries. All these queens, however, are distinguished from the cospecific workers by certain degenerate or primitive characters, which, it would seem, must owe their peculiarities either to the indirect, inhibiting or modifying action of chemical substances (enzymes) in their food or to the more direct action of hormones, or internal secretions produced by the developing ovaries. The great size of the ovaries in the queens of all these social bees accounts, of course, for their extraordinary fecundity and the size of their colonies. Cheshire computed the number of eggs which may be laid during her lifetime by a vigorous, fecundated honey-bee queen as about 1,500,000, and, according to von Buttel-Reepen, we should find in her spermatheca no less than 200,000,000 spermatozoa. It is not surprisisng, therefore, that a hive, at the time of its climax development during the early summer, may contain 50,000 to 60,000 or even 70,000 to 80,000 bees.

In conclusion I may refer to one of the negative peculiarities of social bees—the absence of that peculiar interchange of nutriment between the adult and larva, or trophalaxis, which seems to be a powerful factor in integrating and maintaining the colonies of the social wasps. Among the Meliponinæ the food and egg are simply sealed up in the cell, so that there can be no contact between adults and larva, and even the honey-bee worker does not place the food on the mouth of the larva but pours it on the bottom of the cell where it can be imbibed when needed. So far as known, the bee larva, unlike the wasp larva, produces no salivary secretion to attract its nurses, though it might be going too far at the present time to say that this is certainly not the case. It is quite probable, nevertheless, that the sources of the development and perpetuation of adult and larval contact, so essential to the maintenance of social life among the Bombinæ, Meliponinæ and Apinæ, are to be looked for in other directions. Hermann Müller long ago pointed out, as I stated in the preceding lecture, that the transition of the adult wasp from an insect to a nectar and pollen diet was due to economy of food. These latter substances represent a very concentrated and energizing food supply and one that can be

more readily obtained in great abundance than insect food. Hence it is not surprising that a large group of insects like the bees has become so exquisitely anthophilous, and that the exploiting of larval secretions is unnecessary. It will be noticed that all three subfamilies of social bees store quantities of pollen and honey in open cells and such easily accessible stores of liquid and very finely divided food make even the reciprocal feeding of the adult workers in bee colonies superfluous. This storage of food may be at least one of the reasons why such exchanges of nutriment as we observed among the social wasps and shall see again in a more exaggerated form among the ants and termites were either never developed or were long ago discontinued by the social bees.

THE PATH AS A FACTOR IN HUMAN EVOLUTION

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THE path and the wilderness, formerly in harmony, are now at odds. Certain elements of the wilderness are essential to the best evolution of man. The path is also essential; therefore a reasonable measure of harmony between it and the wilderness should be restored and retained. This restoration and retention might be included in our broad term conservation.

Millions of years before man became human some of the primitive worms and insects made paths; some of the lower vertebrates did likewise, and many of the earliest mammals of remote Triassic times doubtless made paths and runways of many sorts. The Triassic, Jurassic and Cretaceous together constitute the Mesozoic, or age of reptiles, which according to some geologists lasted nine million years; and throughout this long time our earliest mammalian ancestors were small creatures, the largest not exceeding a rat or rabbit in size, hiding for their lives from many a reptilian foe, both large and small.

With the close of the age of reptiles and dawn of the age of mammals, which some estimate to have been three million years ago, mammalian species evolved with great rapidity and in many directions. Mammals small, medium and large, and of wonderful diversity were produced. Of these some still made paths of one sort or another, and many of their constantly evolving offspring continued to do likewise.

Among our modern mammals we now find many famous pathmakers. When man's more recent ancestors departed from arboreal life and remained more upon the ground again, like their remoter pre-arboreal ancestors, they must have made frequent use of the ready-made paths of their contemporaries, some of which fell victims to early man, while others at times made of him a victim. From that time, throughout the many thousands of years of savagery man made an increasing use of paths, himself becoming an important pathmaker where he walked from place to place repeatedly, yet often departing from his paths to search the all-surrounding wilderness.

Some of the ablest students of human evolution to-day assert that earliest man lived in a part of Asia where the physiography and climate were changing so that the abundant rain-forests were gradually forced to give place to a dryer and more open park-like country; changes which obliged the arboreal inhabitants either to migrate or to perish or to modify their mode of life. Potent as such environmental changes may have been as aids to man's transformation from an arboreal creature to a terrestrial man, there were doubtless other deeper-seated factors contributing to the same end. This change from an arboreal to a terrestrial life has been a fruitful field for thought research and discussion among men of science, and it is likely that more thoroughgoing investigation may throw more light upon it. But this is a digression from my theme. Whatever the causes, the fact of the change is plain, and not doubted by any biologist.

Throughout the long, ensuing age of human savagery man had his paths, yet breathed the same pure, dust-free air to which the lungs of his mammalian relatives and ancestors had been accustomed. The lungs of his reptilian and amphibian relatives and ancestors breathed air equally pure.

The age of savagery gave place to the age of barbarism. Some of man's paths became crude streets and highways. Domestic animals, small or large, strayed or were driven along the ways. The wilderness became more netted with paths, and portions of it here and there gave place to crude agriculture. But it still was essentially the same wild, beautiful, fascinating thing. Wonder and mystery, game, adventure, peril, excitement and peace were found in the wilderness. The forests and the mountains, the lakes, valleys and streams ever lured the early children of men to wander into the wilderness, seek out its treasures, and learn its secrets by a life of daily familiarity. Some, less bold, dreaded the wilderness. Some, precocious in urbane awakenings, kept to the beaten paths. Some, indolent or effeminate, stayed to be pampered or scolded by the women. None of them remained within cave or within hut very long, for daylight was preferable to darkness or flickering firelight when storm or sleep did not drive them in. Window glass was not to come until long after civilization had replaced barbarism. Any opening in a dwelling admitted not only light, but volumes of outdoor air. Woman's work must be done out in front of the primitive dwelling place for light. The indoor life could not be lived by any one. Such were our forerunners for countless generations. Our artificialities of the present day are of mushroom growth, having sprung up, as it were, in a moment in contrast to the long ages we have been living the more natural, outdoor life. Our muscles were built for daily exertion, prolonged and varied,

not for the rocking chair, office chair and automobile. Long hunts over the mountains, long toil in the fields or at domestic tasks, these were what trained our muscles, developed our frames, and made our forebears the sturdy, worthy stock from which our virile race has sprung. To-day are any of us wasting, through disuse, our inheritance of strength? Are any developing one-sidedly a well-rounded nature? Do any miss the free, large, open spaces, the virgin forest, the untrammeled wilderness? Do any long to step forth in the morning into a world of natural beauty, reaching out in boundless prodigality as far as the eye can see? Do any feel a sense of loss, as though something great had gone, not easily to be restored? It would not be strange if many felt such secret stirrings, after so long an inheritance in the wilderness and so short an adaptation to our present conditions. The wonder is that so many should have lost, in a few paltry centuries, or even in a few actual years, the inheritance and the instincts of the ages. Man's marvelous plasticity has made possible to-day's civilization. The human species has shown great adaptability and variability, a distinction which is shared by many other species, notably the internal parasites, which have made such peculiar changes of habit and habitat in adapting themselves from a free outer life to a life of confinement and parasitism within some organ of its host. Many and curious are the changes of life habit which these species have undergone; and not only have their habits changed, but their external and internal structures have been modified, in some cases involving the loss of most of the nervous system and all of the digestive system. There has not yet been time for man to undergo any physical changes so far-reaching and so permanent as these, but in the little time in which our European ancestors have crowded their paths and their dwellings together into what we call cities, with their smoke and dust and artificial floor and scenery, our life has changed to such an extent that our bodies are changing in response so quickly as to alarm the trained physical examiner.

Life in factory and office and store and home is as different from the life our ancestors led through the ages as can well be imagined, more different even, in its essential features, than our terrestrial wilderness life was from the preceding arboreal life. The effects on both mind and body are equally radical. The ever plastic human being responds to these inner and outer changes with a speed which, compared with the geological ages of past evolution, bids fair to produce a radically different creature from that which we have known as our human selves in the past.

Three courses are open to us, and a fourth might be conceiv-

able, but this fourth—a complete break with "modern civilization"—does not seem at all probable. These three courses are: (1) that the whole human race be involved in the rapidly growing whirlwind which in its present stage of development we call, rather proudly "our civilization" as though we had deliberately planned it as a complete entity, when no one ever conceived of such a thing, and no one even to-day has the ability properly to evaluate the civilization now in existence; (2) that a part of the human species, reluctant to mutate or evolve into the strange new species which the onward sweep of "civilization" is producing, deliberately keep themselves apart in the yet remaining open places, guarding these zealously as the domain of the creature known to-day by scientists as *Homo sapiens,* the remainder of the race evolving rapidly into some other kind of *Homo,* or even into a different *genus* in time; (3) that the entire race of *Homo,* not wishing to become anything other than *sapiens,* but rather more so, and making use of all his splendid new means of intercommunication the world around, construct an intelligent plan to conserve all the best that the wilderness contained and preserve these perpetually in close conjunction with the best, and only the best, which innovations have to offer.

The wilderness and the path, so easily at odds to-day, must be restored to harmony, a harmony built upon a foundation which cannot again be shaken. The best of all that earth and heaven can yield is none too good for lordly man as he aspires to a better, greater man in future.

Many questions will arise in evaluating the permanent worth of the host of innovations daily pressing their almost irresistible claims upon us. But we will not willingly let the spirit of the machine grind us in its cogs until we are ourselves converted into mere machines of clay, reflecting the nature of the machine—civilization—which ground us.

The great machine civilization, embracing all its component machines and inventions and discoveries and methods of life, would then need to be kept thoroughly human, humanized by all the best that is in the human heart, with all the love of the beautiful, with all the esthetic joy in wild and lovely scenery, with all the satisfying health from breathing air of wilderness purity, with all the thrill of action when the muscles and sinews of the man propel him exultantly through the forest, over the mountains and through the waters. No mere combination of automobile and cloud of dust and office chair can truly satisfy the *Homo sapiens* of the ages. The path must lead quickly to the wilderness. The wilderness must even pervade and beautify the aggregations of our paths. The bare, artificial ugliness of the modern city must be stripped

from it and in various ways replaced by natural beauty. The dust nuisance must be completely removed from all roads and paths, which should be clean and sweet as the woodland lane, and these roads should be so wisely and artistically planned that as few as possible may suffice. The wilderness should everywhere be encouraged and perfected and utilized to the full.

The wilderness is fully able to supply to the maker of paths much which will administer not only to his esthetic joys, but also to his highest and most lasting economic good. The ideal world, in the future, will perfectly harmonize and blend the wilderness and the path.

The function of the path as a factor in human evolution has been apparent throughout the preceding lines. Upon the number, arrangement and nature of these paths, roads and streets depends the nature of our civilization and the nature of the life we lead, and this in turn reacts constantly upon ourselves, "body, mind and estate." By our evolution we mean all those changes which take place in our habits of life and thought, as well as the physical changes constantly taking place in all living beings. Man is one of the most plastic and changeable of beings, quickly responding to factors of every sort.

Man can not, even if he should wish to, remain the same from one century to another. Recent centuries have marked, perhaps, the greatest changes in the given time, for the greater changes in our past were the product of uncounted ages. The path will always be an important factor in our progressive evolution by reason of the profound, or better, the fundamental bearing it has upon the kind of life we lead and the kind of being we are or are to become.

Where the path leads man will follow. To the kind of path man's foot conforms itself, and his lungs and his mind and his muscles and his stomach and his spirt are all affected directly or indirectly by the nature of the path and where it leads. Man may to a great extent be the creator of the world he lives in; he will always be its mirror.

WHY DO WE LAUGH?

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ONLY those who have taken the world seriously can see the humor of it, and only those who have a keen sense of humor can afford to take it seriously. The funny grows out of the serious as much as it grows out of the humorous. It is only in so far as the ancients took themselves and their dogmas seriously that we can laugh at them; when we find them laughing at themselves we have hit upon something worthy of our serious consideration, for their laughter is the gauge of their seriousness.

It is the serious which unwittingly reveals the shallows, as it is the comic which often plumbs the serious to its depths. It is only because the child takes his pretensions seriously that we find them funny; his merriment is not itself funny, though it may sympathetically arouse us to share his laughter. In the latter case, however, we laugh with rather than at him. Oliver Wendell Holmes has said that we start by laughing with a man at his jokes, but in course of time come to laugh at him. This happens only when he attaches too much importance to his jokes.

As laughter is one way of appraising the serious, so the comic must be taken seriously if it is to be rated at its true value. No one understands a joke by laughing at it; he laughs at it because he understands it. He must moreover, understand it in a flash, not by a gradually dawning comprehension. To arouse laughter, his appreciation of the "point" of the joke must be almost instantaneous, however long he may be in preparing for that appreciation. He must have a direct and clear intuition of the situation, rather than a dim consciousness of it. He must see it in its fullness rather than in its parts.

Laughter is essentially a social phenomenon, almost as much so as is language itself, the two being very similar in origin as in function. "Laugh and the world laughs with you" may be true when there is a world society; at present, "Laugh and your social group laughs with you" would come nearer the truth. Or let us put it differently and say that when you laugh and how you laugh depends upon how and when your group laughs, much as your sentiments and language are determined by the sentiments and

language of the group. As people mumble to themselves, so they may chuckle to themselves; yet laughter is no occupation of a Robinson Crusoe, but the pursuit of a man whose life is spent amid that of his fellows. Laughter, moreover, serves a useful purpose in group life, especially on the lower levels where solidarity and uniformity are necessary in the competition with surrounding groups. It implies a common standard and is an efficient instrument in holding the group to that standard—a much more efficient instrument than scolding. A man who cannot laugh is no social being and is scarcely human. We find no human societies in which laughter does not figure as part of the social life, as, in fact, a part of the group language. If scorn is the lash, laughter is the jolly policeman who keeps the social traffic going after the approved manner, whose power inheres not in itself, but lies in the tribal standard which it bodies forth. Ethnologists have not found a group of human beings who are devoid of laughter of this sort. A few examples of the expression and repression of laughter in primitive society will make clear its social utility.

In their perverted pedagogy, the Australians teach the youths what to do by showing them the things they should not do. As part of the ordeal of training through which the young men pass when being initiated into the tribal life, the old men perform ridiculous pranks which the youth must watch, always restraining the laughter which they tend to give way to at sight of these exhibitions. A large part of these initiation ceremonies is designed to give the young men a respect for their elders, this being one way of inculcating such respect. Laughter at a person is, in a sense, an assertion of superiority to him, and the youths may not risibly make such assertion. The performance would be ridiculous if done by any other than the aged. Performance by the aged takes it out of the realm of the laughable, for the elders set the standards for the group. An aged Fijian told Erskine that he was going out to bury himself because he could not stand the jeers and laughter of the ladies of the tribe, and said some caustic things about the callousness of a European who did not care whether he was laughed at or not. An Eskimo has little of the sensitiveness which we associate with the intimacies of domestic life, but he cannot stand the derision and laughter of a rival. He will sometimes break over the tribal rules and kill the man who laughs at him. He laughs best who laughs last—that is his argument, and it is a convincing last word in the dispute. The tribesmen in the plains area of North America are among the most tireless and daring warriors in all primitive society, yet they can not stand the laughter, directed against them, of their fellow-men. Laughter is one

of the principal means of holding in line the members of the various warlike organizations which flourish in these tribes. A man of one of these societies who resents the abduction of his wife by a fellow-member, this being no violation of the rules of his order, is laughed at by the other members of the organization until his resentment passes.

Let these examples suffice. They show that laughter is a means of expressing and maintaining the group standard. It reminds people of their place in the social group and is an efficient, if gentle, reminder that they had better keep where they belong. It is an expression of the proprieties of the occasion to which the individual must attend.

When a person laughs at himself, he is, in the main, assuming the group standard, applying to himself the standards which the group applies to him. He assumes in his own person the duties of policing his conduct.

Little wonder, then, that the group should regard with serious concern the individual who is lacking in the faculty of laughter. He is largely on a par with the man who can not render military service to the group, who can not serve his fellows in the very important enterprise of bringing into effective use that group standard which makes for unity, though for unity at the price of uniformity. He may be amenable to group standards, but he is useless in the important task of holding others to that standard.

Laughter, it follows, is individually as well as socially self-preservative. The laughter of the virtuous man is not that of the vicious, for the virtuous and the vicious belong to different groups and are maintaining different standards. There is no equality in which there is no equality of laughter, no democracy in which there is no democracy of laughter, no shifting of standards unless there is a shifting in the things which elicit laughter.

There are, of course, marked intellectual elements in laughter. The individual may laugh at the group and at their laughter. Whether he does so depends upon his appreciation of group standards and upon his acceptance of them. His laughter at them expresses this assumed superiority over them.

Perhaps the most frequent intellectual element in the situations which elicit laughter is recognition of the unusual or of the unexpected. This frequently harks back to appreciation of departure from, or unexpected conformity with, group standards. We suddenly perceive the situation as in keeping with, or as out of keeping with, the social program, as a neat way of humiliating the haughty, subduing the insubordinate, or thwarting an unexpected departure from social routine. The intellectual element is largely social.

A like-minded social reference tints the psychological elements accompanying laughter. The experience is usually pleasurable, though this is conditioned by the extent to which our laughter is taken up by others who are present, that is, by the extent to which it is appreciated by the group. To laugh when no one laughs with you may be painful.

Laughter is not always elicited by the pleasurable, nor is it always the expression of pleasure. It may be a means of expressing displeasure at personal pretensions. We may laugh in spite of ourselves, though to the spite of another, and to our shame and remorse, ashamed and sorry even while we laugh. These uncontrollable outbursts show the extent to which we are held in the grip of the group standard, and the extent to which we enjoy our assumed superiority.

This sense of elation upon the part of the laugher is almost always present. It is not the mechanism of the man who stumbles or fumbles which arouses our laughter, as Bergson would have us believe; it is rather our elation at our own superiority. If we know that we must immediately pass through a similar test and will do no better than did he, his action is to us not nearly so funny as it would otherwise be. We laugh at the sprightly middle-aged man whose sight and agility should have saved him from the banana peel; but we pity rather than laugh at the aged cripple who had not these aids of discrimination and ready reflexes. Yet the latter action is much more mechanical than the former. It is true we recognize our superiority to the latter, but we do not recognize it in any sense of elation, for we have not placed ourselves on the same plane for comparison. With the middle-aged man who is like unto us it is different: he indiscreetly does what our discretion would not permit us to do. The behavior of the feeble-minded elicits no laughter from those who have a lively sense of what feeble-mindedness means; but these same actions may elicit laughter from those who do not know that the performer is feeble-minded, or for whom this information conveys no real knowledge of his condition. We laugh, in fact, not so much at the act as at the person performing the act. This is as true of the situation on the stage as of those in daily life, when alone as when in a group. Pascal asked: Why do we laugh at a fool, but do not laugh at the cripple? and answered: The one is crippled in mind, but does not know it; the other is crippled in body, but knows it. But, as was mentioned, if he is a congenital mental cripple, we do not laugh at him; it is only because he ought to know better that we laugh at him, never because he can not know better.

Now laughter, like any other social tendency, easily overflows

the channels of its social usefulness and may become a social calamity rather than a social blessing. We often find it purposeless rather than purposive, controverting rather than supporting the principles which we have laid down. This may call for a more careful orientation but does not contradict our explanation of origin and function. As you can not disprove the physiological utility of hunger and appetite by pointing to dyspepsia, nor the use of language by pointing to solecism, so you can not disprove the use of laughter by pointing to its misuse.

If the above explanation of laughter arouses the laughter of the critic who reads these pages, his hilariousness will prove my point, for it will be an expression of his intellectual disapproval and of his personal elation of superiority; and if he does not laugh at it, but takes it seriously, I assume that he has discovered in it some elements of truth which may turn the laugh on rival theories.

SOME PROBLEMS OF PROGRESS

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PROGRESS is the controlling idea of western civilization. The man on the street discusses it as much as the philosopher. The most reactionary claims it no less than the radical. It has its place in the campaign material of the politician and comes into the exhortations of the preacher. In fact it is the most widely accepted doctrine of the present day. Yet the state of progress is an accomplished fact only in one of the great divisions of human activity, that is, in science. In the fields of economics and government, for instance, it is only a hope and an expectation. I am not using the term progress in the sense of a sequence of events, not as the state implied by "we don't know where we are going, but we are on our way." I am using it to denote a state of continuous advance with ever increasing rapidity toward an ideal yet definite goal.

The state of change in the field of government or of economics can not be called progressive in the above sense of the term. Great changes have taken place in these fields during the last 150 years, but their character has been impulsive and intermittent, accompanied with backward and forward oscillations. The political history of France from the revolution to the present day is a case in point. Even the history of this country during the same period is no exception. Although reactions comparable with those in France have not occurred in this country, it must be admitted that two of the three great steps towards an ideal of democracy were the result of revolution and of war. The third great step, the extension of suffrage to women, was accomplished by peaceful means, but as a setback we have the constant weakening of the actual if not the theoretical power of the citizen as a voter, which has been going on during the last one hundred years as a result of superficial expansion of democracy without commensurate growth in depth. The lack of simultaneous development of democracy along other lines—principally along economic lines—has introduced into the body politic forces and machinery which have made the franchise as meaningless to the average citizen as the right of a small stockholder to vote in the affairs of a large stock company. The

extension of Hobson's choice by our two-party system is counterbalanced, it is needless to say, by the practical identity of the aims and methods of the major parties.

If we consider any actual event as a necessary and inevitable link in the chain of history, then the present is in advance of the past whatever the character of the present state. Even a long swing backward along the road is a forward stretch if it is unavoidable. If we do not take this fatalistic view, however, it becomes debatable whether we have advanced far, if at all, during the last hundred years in the totality of our theory and practice of democracy, social and economic, as well as political.

The intermittent method of advance in the fields of economics and politics has, in the past, been destructive of wealth, of human lives, of happiness. It has given rise to suppression, revolution and war. It has aroused intense hatred between classes and races. It has produced the misery of filthy slums, on the one hand, and the debauchery of irresponsible wealth, on the other. If this method has been ruinous in the past, it may become fatal, at least to western civilization, if persisted in in the future. This is the supreme lesson to be learned from the last war and from the developments of instruments of destruction. Western civilization is at the parting of the way. It may follow its predecessors in the path of destruction or it may strike out into the new path blazed by science.

The idea of progress is less than three centuries old. It did not become a generally accepted principle until after the middle of the nineteenth century, and even then only in the western world. Its late appearance in the history of civilization is due to the world-wide misconceptions, incompatible with the idea of progress, which prevailed in the past with regard to the origin and destiny of the human race and of its habitat. The Ancient Greeks believed in the cycle theory of civilization. History repeated itself in a series of cycles. Nothing was, or could be, new under the sun. On the other hand, the Christians have followed the Hebrews and earlier oriental peoples in believing in the initial degeneration theory, according to which man and his world were created perfect only a few thousand years ago, but on account of "man's first disobedience" and fall his race and his world were condemned to a relatively short and miserable existence and to a final destruction, except for a chosen few who were to be saved from the wreckage of mankind.

There is no room for the idea of progress in either of these theories. Therefore a reasonable doubt as to their validity was necessary for the birth of the idea, and a more or less complete

overthrow of the theories for its growth and general acceptance. This was accomplished by science. It showed that man has evolved from lower stages of animal life to his present position during a series of geologic periods of immense duration, and that he is likely to exist on the earth for unnumbered generations to come without fear of the world coming to a sudden end. Furthermore, science demonstrated that with his present biological heritage it is possible for man to take great strides with ever increasing rapidity toward understanding nature, formulating her laws, directing her forces and applying them to life. In short, science made it possible for man to cast aside his gloomy outlook of life and his attitude of helplessness, and to take the destinies of his race into his own hands.

But if man is really to control his destiny the state of progress must be more than a hope and an expectation in all of the major fields of human activity. The research spirit, the unbiased critical mind and the experimental method of the scientist must prevail in the fields of politics and economics as well as in science.

But are not the problems of government and of industry very unlike those of science and far more difficult? Nobody can deny the great difference between the problems, but any problem, if it is to be solved, must be analyzed, formulated and eventually solved by the human mind. The general line of approach must, therefore, conform to the fundamental laws of operation of the mind. There is no reason, theoretical or experimental, why the scientific method which has proved equally successful in such varied subjects as astronomy and biology should not yield great results in the fields of government and economics. As to the relative difficulty of the problems no useful purpose is served by a blanket admission, or denial, unless it is followed by a careful analysis of the causes which contribute to the difficulties. It is safe to assert, however, that the greater the difficulty the more forceful is the reason for applying the only general method which has proved to be invariably successful.

II

My object is to point out some of the prevalent theories which are blocking progress in the fields of government and economics (at least as they appear to one scientist), to indicate some of the lessons which we could learn from the history of science, and to outline a plan by which the scientific method might be applied in these fields.

Tradition has been the most formidable enemy of progress in all ages and in every field. Disguised in the latest and most popular fashions it has always worked to arrest progress or to misguide. In the semblance of the guardian of souls, as the custodian of

public morals and safety, in the guises of patriotism, of authority, of loyalty and in many other more or less reasonable attires, it has played havoc with human intelligence. It has been driven out of the domain of science, but in the fields of government, economics and religion it still holds its own. We have heard so much about the conflict of science and religion and so little of any conflict between science and politico-economics. Yet there exists a real conflict between science and the rest, not so much because of differences on specific questions, such as the origin of the world, but because of the incompatibility of tradition with scientific spirit.

Only three centuries ago tradition ruled supreme in science. For two thousand years the western world had looked back with eyes fixed on Aristotle, producing a hypnotic state which made progress wellnigh impossible. Galileo broke the spell by a single crucial experiment. For centuries the world has been taught by tradition that heavier bodies fall faster than light ones. Galileo took a number of balls of different weight to the top of the leaning tower of Pisa and by dropping them showed that they all fell at the same rate. The effect of this simple experiment was startling. It established once for all the experimental method as the supreme test for truth in science.

It is interesting to note in this connection the state of mind which tradition creates. The learned professors of the university of Pisa would not believe their eyes. "Does he think," they said, "that by such experiments he can shake our belief in the true philosophy which teaches us that a hundred-pound ball falls one hundred times faster than a one-pound ball? Such disregard of authority is dangerous." In the light of three hundred years of scientific progress these men appear ridiculous to us. Could we see ourselves in the light of a commensurate progress in politics and economics we might be given to greater charity.

One of the obstacles in the way of progress in economics and government is the prevalent conception of the function of a natural law. As an illustration, consider the statement "the laws of economics are just as immutable as the law of gravitation," which is often used as an argument against any change in our economic organization. To the scientist no law is immutable. However exact our laws may be, they are subject to future revision and extension. Einstein's modification of the law of gravitation is a new evidence of the soundness of this position. The real aim of those who argue the immutability of economic laws, however, is to imply that attempts to alter the conditions under which these laws operate amount to attempting to change or to suspend the laws themselves and consequently are doomed to failure. This is about as sensible as

telling a hydro-electric engineer who is building a canal to divert the waters of a river that he is attempting to suspend gravitation. The law of gravitation operates whatever the condition under which water is made to flow. Similarly the law of demand and supply, for instance, operates under all economic conditions. Whether or not its operation under certain conditions is more conducive to progress than under certain other conditions depends upon the conditions. This question can only be decided by a comparative study of the actual operation of the law under the two conditions and not by arguments regarding the immutability of the law.

Let us take another illustration, this time from the field of government. Chief Justice Taft said in a recent decision, "The Constitution was intended, its very purpose was, to prevent experimentation with the fundamental rights of the individual." I suppose this interpretation is historically correct and justified. The framers of the Constitution were very much impressed by the encroachments on the most elementary rights of the individual by Kings and other government functionaries in the past and wanted to guard against such possibilities in the future by constitutional guarantees. But the problem in this connection has become rather a question of adjustment of the rights of individuals than one of safeguarding them. The time has come therefore to take the position that our conception of individual rights is in the process of growth, that conscious experimentation is one of the factors which should contribute to this growth, and that the constitution should become a guide for and not a barrier against such experimentation.

Again there is a widespread feeling that certain fundamental conditions necessary for progress in government and economics are lacking. This feeling is often expressed by the statements "You can not change human nature" and "change of heart must come first." But are these conditions necessary? Science has shown conclusively that they are not. It is fortunate indeed that they are not. For if progress were conditioned by a change in the nature or in the emotions of man all hope for progress would vanish into thin air. Human nature has not changed appreciably since the stone age. The vast amount of effort expanded during historical time with the explicit object of affecting a change of heart has produced notoriously little result. These conditions are neither necessary nor attainable within a reasonable length of time.

There is a condition, however, which is both necessary and within striking distance, that is a change in the environment, in the atmosphere, in which human nature functions. The civilized gentleman of to-day behaves differently from his ancestors of the

neolithic age because the environment has changed and not because of a change in human nature. The soldier in action with his trench knife in a German dug-out of the western front is not a wild boar using his tusks. He is the same man whom you and I used to know as a fine young man. He has had no change of heart. The stimulii have changed, that's all.

The importance for the future of mankind of a clear understanding of this point can not be exaggerated. By focusing attention upon the improvement of the environment in which his nature functions and upon changing the stimulii which actuate his motives and impel his passions man may achieve in the next four centuries the results which he has vainly striven for during the last forty centuries by trying to change the human heart.

A number of biologists have warned the people of this country of a grave danger which is threatening to lower the hereditary qualities of the American people. They claim with good reason that civilization has upset the processes of natural selection. If this warning is to produce the desired result, however, it must not shift the main emphasis from the improvement of environment to questions of biological selection. The surest and shortest course to the improvement of our biological heritage lies through the betterment of the conditions which make progress possible. We can not afford to confound evolution with progress.

Another fallacy which has impeded progress in all ages is the bugaboo of the danger lurking in the person of the radical. Now, what constitutes a radical? Is he really dangerous in the sense that the general public is made to understand it? In order to obtain answers to these questions which will be free from the prejudices due to the *mores* of any one land or of any one age, we must make a critical study of the history of the radical in all lands and in all ages. If we do this we find, first, that the radical has generally been a man of ideals. His ideals have not always been very high nor his ideas very practical; yet it must be admitted that his radicalism has centered around ideas and ideals. Secondly, that most of the great reformers in religion, in politics, in science (until recently), and, in fact, in all important phases of life have been accused of dangerous radicalism by their contemporaries. Thirdly, that the radical of history has proved to be infinitely less dangerous than the ambitious or the greedy. If there is one supreme lesson to be learned from history, it is the fact that personal ambitions rather than ideas have proved to be disastrous to civilization.

Go through your ancient and modern history and count the number of wars, for instance, which you can conscientiously lay at the door of the radical, and then remember that the inocuous conservative had his share in the few revolutions for which the

radical of history has been responsible. It is decidedly unfair to deprive King George the Third of a small share in the glory of the American war of revolution. It would be interesting and instructive to speculate on the course which the history of the world might have taken had the radicals of Germany in 1848 and those of Russia in the sixties succeeded. Would Carl Schurtz and his friends have proved to be as dangerous as Bismarck and the ex-Kaiser, or Chaikowsky and his "circle" as destructive as the late Czar and his entourage?

One of the most potent factors which has contributed to progress in science is the habit of the scientist to draw general conclusions from carefully considered specific data. This is called the inductive method of science. After finding that two apples plus two apples make four apples and that this rule holds true for rabbits and a number of other objects he arrives at the conclusion that the rule holds for all objects. If a child had to learn the addition of each type of objects separately how fast and how far could it progress? Yet man has behaved when confronted with a new idea like such a child, especially when the new idea happened to concern his dominant interest. When philosophy was the dominant interest in Greece Socrates was accused and condemned for "corrupting the youth." At a time when religion was all important in Judea the custodians of public morals arraigned Jesus before Pilate with the charge "We found this fellow perverting the nation." When tradition and authority of the church were considered of supreme import Galileo was sentenced to death for "disregard of authority." "Heresy," "sedition" and "disloyalty" have been the magic words in all history which have set the hangman's noose into action.

We have learned to tolerate differences of opinion on matters of religion, to take a sympathetic attitude toward political refugees from other countries, and even to welcome new ideas in science. But when it comes to questions of economics and industry we draw the line. We discuss the French revolution with equanimity. A mere reference to the American revolution fills us with pride. But when it comes to the Russian revolution the situation is completely changed. We can not see any good in it. We don't want to see anything good come out of it. Questions of transmission of religious control and of political power through heredity do not excite us for we have never believed in khalifates and have settled the question of the divine right of kings. But we can not consider with composure questions of transmission of economic power through inheritance.

This is an age in which economic questions and problems of government affecting economic conditions form the sacred grounds

where one must not trespass. Yet absolute freedom of discussion is far more necessary for progress in economics and government than in science. The scientist can usually put his theoretical solution to the test of experiment. He can often build a model to demonstrate that his solution is practicable. The student of economics and of government is less fortunate. To be conclusive the experiments in his field have to be carried out on a vast scale in the laboratory of life, over which he has little or no control. The economist who works out a solution for the problem of the most efficient organization and operation of the railroads of this country can not build a model of the country with Belascovian detail and show the skeptic that his solution is workable. On account of this handicap, the widest possible opportunity should be open for free discussion of actual as well as proposed solutions of political and economic problems. This is the absolute minimum necessary for any possibility of progress in these fields without recourse to revolution.

Since the world war, many a well meaning person in this country has tried to do away with this minimum on the ground that criticisms of existing conditions and discussions of possible changes are subversive of democracy and consequently unamerican. These persons either do not understand the implications of democracy, or have no confidence in the ability of the people to exercise their constitutional rights. If the people have to be sheltered and protected against contact with new ideas, good or bad, they can not be in a position to govern themselves. Censorship of ideas and true democracy are incompatible and mutually exclusive.

The road of progress ever penetrates into new and unknown territory. Exploring, surveying, blazing, felling trees and clearing the underbrush are just as essential for the extension of the road as laying the foundation and putting on the top dressing of the road in the cleared sections. It serves no useful purpose for those engaged in the later stages of the construction to call the others idlers or destroyers.

Another popular misapprehension which deserves our attention relates to the function of parties in political progress. We are not interested here with the merits of party government compared with other democratic forms of government. Given the party form of government, what is the proper conception of the function of parties? That is the question which we want to consider. Persons occupying exalted position in one of our major political parties have attacked independent organizations such as the League of Women Voters on the ground that political influence should be exercised only by bodies organized explicitly as political parties.

One might just as well claim that all research and education in the theory and application of electricity must be carried on through duly incorporated electrical companies, preferably through the Westinghouse and the General Electric companies. Electrical stock companies are organized for the express purpose of making money for their owners and not to carry on research and educational work. Their function is to supply the country with electrical machinery. If they do a little research work it is only to keep one step ahead of their competitors. Education means to them the training of the public to buy their wares. The main body of research in electricity has been carried on in the study room of the mathematical physicist and in the laboratory of the experimental physicist. Education has been and will always be the work of non-money-making institutions. The situation in government is analogous. The object of parties is to win political campaigns. Their function is to administer the country in the way the majority of the people think it should be administered. No party is qualified, or can afford, to carry on research necessary for political progress, or to teach the public the results of recent researches. Political education and research work in government must be carried on, as we are now organized, by individuals and by non-partisan organizations, if we are to have progress in this field.

III

So far our discussion has centered mainly upon the contrast between the spirit and attitude which prevails in science, on the one hand, and in politico-economics, on the other. We will now consider the scientific method of progress and see in what way it might be applied to questions of government and economics.

The scientific method of progress consists of two complementary processes. In one of the processes facts, collected through experience, observation and experiment, are used to obtain relations among measurable magnitudes such as length, time intervals, forces, etc. These relations are then assembled into an ideal structure. Geometry and the science of electrodynamics are examples of such ideal structures. In the second process these ideal relations become guides for the proper handling of known data and for the discovery of new facts and relationships. The first is the process of the building up of a theoretical system; the second is the process of the application of the theory. The two together form the wheels upon which science progresses. Without theory practice reduces to the rule of thumb. Without the facts obtained by practice theory becomes unmanageable.

There are two important details connected with the scientific method which deserve special mention. First, the scientist defines

as clearly and unambiguously as he possibly can every word which represents an important concept. Secondly, as his ideal structure grows by the discovery of new facts and relationships, he takes scrupulous care to make it more stable and harmonious by rearranging, by altering and, if necessary, by discarding certain parts.

The work of the students of the foundations of geometry of the nineteenth century and Einstein's achievements are examples of how the scientist searches even the deepest and most solid parts of the foundations of his ideal system for flaws, for weak points, for incongruities. For 2,500 years Euclidian geometry had stood the test of experiment and of the strictest logical thinking of the greatest human minds. Yet the geometrician was not satisfied. Is the postulate of parallelism an independent assumption or is it a consequence of the other axioms of geometry? That was the question which he asked relentlessly and for which he finally obtained an answer that brought with it new systems of geometry. The Newtonian conceptions of space and time formed the solid foundation of the marvelous structure which science has erected during the last three centuries. Yet Einstein asked himself "Are these conceptions of space and time true to nature?" and found an answer which opened a new world for science and philosophy.

In the fields of economics and government there is nothing comparable with the two complementary processes which form the scientific method. There is too much operation in these fields, and too little science, too much of carpentry and too little of geometry, too many operators of electrical machinery and too few who understand electrodynamics. Students of government and of economics appear to be more interested in the operation of the present machinery of organization than in the creation of new and more efficient machinery, or in the building up of an ideal structure with which existing organizations could be compared.

Have the students of the foundations of government (if such exist) examined the famous trio of liberty, equality and fraternity to see whether these foundations of democracy are compatible with each other and with nature, or whether the traditions, the laws and the conventions of democracy are in consonance with its basic principles? Is it possible to have both liberty and fraternity? Is there equality in nature? In what way should liberty be defined so as to bring it into harmony with the responsibilities and the consequent constraints implied by the postulate of the brotherhood of man? How should democracy be organized so as to satisfy the aspirations of man expressed in the term "equality?"

The foregoing questions could be answered and a scientific

theory of democracy could be developed if a group of brilliant scientists could be induced to devote ten years of their lives to the study of democracy in government and in industry, and if they could be organized for concerted effort. The group would have the following objectives.

First: To discover and to formulate a set of postulates, or principles, which are necessary and sufficient for the building up of a theory of democracy, having regard to the adaptability of the theory to life and of the postulates to the theory.

Second: To erect upon the postulates adopted as foundations the theoretical structure of an ideal democracy which will be rational and self consistent.

Third: To draw up a working plan by which our actual democracy could be approached by successive approximations to the ideal, say, during the next one hundred years.

The experts working for the first objective would be mainly mathematicians trained in the foundations of geometry and logicians like Bertrand Russell. The group drawing up the working plan would contain natural scientists, engineers, psychologists, economists and men of practical experience in government and industry. The group working for the second objective would contain all types of experts.

I do not want to give the impression that the foundations and the superstructure of the theoretical democracy and the plan for its materialization could be final. For a scientist finality has no meaning. The theory as well as the working plan would be modified and improved constantly in the light of new experience. Yet I am confident that even the first draft of the theory would be a good enough model for the irrational and inefficient existing systems to copy. Nor am I under the illusion that there is a moderate chance of the working plan being adopted by any country. The usefulness of the scheme which I am proposing would be increased if the plan could be adopted. Beyond that the question of its adoption is not relevant to the scheme. Most of the researches in mathematics and in natural sciences are carried on with little or no expectation of practical application. Some of the most useful applications of science to industry have come about indirectly from researches which had appeared to have no possibilities of practical application. The most useful engine ever invented is Carnot's ideal engine which can not be constructed except in idea. If direct application were the deciding factor in the development of mathematics and of natural sciences we should still be savages. The scheme I have suggested would have its greatest usefulness through its indirect reflection upon society.

BACOT, A MARTYR TO SCIENCE

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ABOVE one of the portals in Memorial Hall at Yale is the inscription, "We who must live salute you who have found strength to die." This sentiment is dedicated to those students who gave their lives on the battle field for their country. No village or hamlet in this or any other country is too small to have a monument to its soldier dead. Romance, fearless heroism and tender memories crystallize out of wholesale human combat. But there have been other struggles which have claimed their share of human interest—spiritual contests, strife against fear and superstition and struggles against disease and pestilence.

The advance of civilization has been made quite as often by individual effort as by group endeavor. In the history of progress in medicine we have countless instances of men who have unselfishly spent their efforts in study and tireless experimentations for the advancement of knowledge. And then we have those selfless souls who have given not only their efforts but their lives in the struggle for mastery over ignorance and disease.

The story of the conquest of yellow fever must always bring to mind the brave group of army surgeons who carried on their experiments among the mosquito-infested swamps of Cuba immediately after the Spanish-American war. One of the men, Dr. Jesse W. Lazear, died with yellow fever, contracted through the bite of a stray infected mosquito which he refrained from killing in order to study its method of attack and because he feared to disturb the patient on whom he was working. That fact is stranger than fiction is brought home to us again in the account of the discovery that Rocky Mountain fever is transmitted from one animal to another by ticks. Through the brilliant work of Dr. H. T. Ricketts we now know that at times the adult tick accidentally bites man, thus causing spotted fever. After isolating the organism responsible for this disease, Ricketts turned his attention to typhus and discovered that this affection also was transmitted by an insect. It was while pursuing this work in Mexico that he was stricken with typhus and died. Both Lazear and Ricketts were fully aware of the virulence of the disease they were

studying, yet neither hesitated in his attack on the unknown. The fact that these men fought an intangible and elusive but none the less deadly enemy with the instruments of the laboratory and finally gained a victory for human welfare entitles them to a place among the heroes whose praises are seldom sung but upon whose achievements the comparative comfort and safety of our present life so largely rests. It is the account of the latest of these martyrs of science to which I wish to refer.

The British medical news dispatches have recently reported the death on April 12th of Arthur William Bacot in Cairo. In January, 1922, he had gone at the invitation of the Egyptian government to carry on further investigations on typhus, not as a result of a serious outbreak of the disease, but in an effort to obtain more definite information about it for preventive measures. Mr. Bacot contracted typhus while handling infected lice. The career of this professional-layman who has contributed so much to our knowledge of insect-borne diseases is worthy of special notice.

Until 1910 he was a clerk in London. On Saturday afternoons and on Sundays he crept away from his drudgery out of the city into the country and pursued the study of entomology with passionate zeal. Apparently he developed his powers for careful, detailed observation on these week-end trips, for one of his early discoveries was that the eggs of gnats will not hatch in absolutely clean water. He became known as an expert on the Lepidoptera and published accounts of his remarkable experiments upon the breeding of moths. In all of this early work there was shown evidence of a skill and fineness of technic which was to be useful to him in his later work; and the enthusiasm and freshness of outlook of the amateur became so firmly developed that his later professional entomological work was uniquely characterized by these very qualities.

Until he was past the prime of life, science was his avocation. In 1910 came his first commission of a professional nature when he assisted in the study of the bionomics of fleas for the Indian Plague Commission under the auspices of the Lister Institute. As a result of his excellent work, he was appointed to the post of entomologist of the Lister Institute, an advancement which was more than justified by his subsequent achievements.

During the next three years he played an important part in discovering the mechanism by which the plague is conveyed from rats to man by fleas. Then he went to West Africa and studied yellow fever, writing a masterful report on the bionomics of the mosquito responsible for its transmission. It is significant that he should make a distinct further advance to our knowledge of the

etiology of this disease, a subject to which American investigators have contributed much and in connection with which another martyr, Dr. Lazear, gave his life more than ten years before.

Since 1916 Mr. Bacot had focussed his attention on the biology of the louse. With remarkable attention to detail he has given us an account of the growth and moulting of the louse, length of life, method of ovulation, feeding habits, effect of temperature and food supply on activity—in short, a complete compilation of the bionomics of this insect. While these studies were in progress the experimental animals had to be fed and, since the natural habitat is the clothing next to the human skin with blood as their food, it devolved on Bacot to devise methods for keeping these lice in captivity and at the same time to feed them. During these and subsequent years he kept his colonies of stock lice in small, round cardboard boxes, one end of which was covered with chiffon so that when occasion arose, the boxes could be fastened on his arms, legs or body and the lice given opportunity to feed. Mr. Bacot realized that many insecticides were not subjected to practical tests before being advocated for use, for that which was effective in the atmosphere of a closed bell jar in a laboratory might be absolutely useless when applied under the clothing next to a moist skin at 85°. He planned and carried out experiments testing insecticides, the lice and the substance to be tested being suspended in cloth bags under his shirt next to his skin. To read, in his own words, of the matter-of-fact way in which he considered these unusual procedures is to have an insight into a type of personality which relegates self to the background and considers steadfastly the final goal of its efforts. Here, in truth, was an effective union of mind and body in service to mankind.

These studies prepared him for similar work of a more specialized nature, and in 1917 the War Office saw fit to put him on the committee for investigating trench fever. This disease had been playing havoc among the British troops. It was reported that at one time 60 per cent. of all the cases of sickness were those due to trench fever. According to another report, it caused nine tenths of all the sickness in one of the British armies. The incubation time of the organism, determined later by experiment, varies from fourteen to thirty-two days. The victim is suddenly seized with dizziness, pain in the legs, headache and pain behind the eyes while his temperature rises to 103 or 104 degrees. Skin manifestations may occur as erythematous patches. The first attack may last a week, then subside only to appear as a relapsing type at intervals of a week or more, each attack lasting from two to eight or more days. The fever may persist for as long as sixty

days with a moderately high temperature. Although the disease is rarely fatal, it is obvious that even a moderate prevalence would seriously handicap military operations.

Through the efforts of Bacot and his associates on the trench fever committee, the mystery surrounding the etiology of this affection has been cleared up. It was shown that the malady was louse-borne, that lack of opportunity to change clothing and uncertain bathing facilities incident to field conditions contributed to its spread, that a louse which had bitten a victim was capable of transmitting the disease to another person through its bite, that inoculation could be obtained by rubbing the feces or body tissues of the louse into a broken surface (as might be done in scratching), and that the dried urine of the victim was infectious. In addition, Bacot showed that in the intestinal tract and feces of lice capable of transmitting trench fever there occurred cocco-bacilli-like bodies, not stainable by the ordinary bacteriological methods, but which were similar to the rickettsia of Rocky Mountain fever. He later decided that the rickettsia of trench fever were identical with those seen in cases of relapsing fever. Such clear-cut evidence, pointing the way to very definite methods of combatting this affection, was particularly welcome at this time of stress and established Bacot in the front rank of medical entomologists, though he was not trained in medicine.

In 1920 he went to Poland as a member of the Typhus Research Commission of the League of Red Cross Societies. He took his own supply of uninfected lice which he had bred and grown in his London laboratory and which he maintained on his own person. After arriving in Warsaw several months were lost due to lack of laboratory facilities. Before active work on typhus was begun, Bacot fell sick with trench fever. During the course of his illness he kept accurate notes of his symptoms and fed lice with his blood. He observed the appearance of rickettsia in his stock lice which until his sickness had been free from them. During his convalescence and for some time afterwards, he followed the occurrence of rickettsia in the lice which he had fed and was able to show that the blood of trench fever patients when fed to lice caused the appearance of these bacteroid bodies in the lice as long as three months following the clinical recovery from the disease.

After returning to England Bacot continued his studies on infection of lice. Late in 1921, before the Royal Society of Medicine, he gave a demonstration of a method for louse infection. The procedure involved the rectal injection of blood into the louse with a capillary pipette while the insect was held under a slip of paper on the stage of a binocular microscope. All who saw it were im-

pressed by the skillful technic and dexterity shown by Bacot during the course of the demonstration. Working with these minute animals, using specially devised microtechnic, Bacot fully realized the dangers to which he was exposed because of the infectious character of the excreta of the lice, once they had fed on typhus blood. These facts serve to emphasize the high order of purpose and intensify the sacrifice he made.

An American architect recently said that the English really know how to live. If they know how to live, they also know how to play and many of them have achieved that happy combination—the proper relation of their vocation to their avocation. The typical Briton works at his stint that he may support his hobby and it is in the pursuit of the latter that he lives his life, expands his soul and produces. In the personality of Mr. Bacot we have an example of just such a balance between that which must be done and that which pleases to be done. His hobby became his ruling passion, gradually absorbed his whole life, lifted him to eminence and finally placed him among the immortals—those who have given their best that others may better live.

MODERN STUDY OF THE ATOM

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Reality of Atoms and Molecules

IN the latter part of the last century many distinguished men of science still doubted that reality underlay the atomic and kinetic theories and therefore preferred to deal with chemical phenomena mainly from the standpoint of energy changes. Chief among these prophets of the energetic school was Wilhelm Ostwald. After working over the material for the new edition of his "Outlines of General Chemistry," however, Ostwald wrote in 1908: "I am now convinced that we have recently become possessed of experimental evidence of the discrete or grained structure of matter, which the atomic hypothesis sought in vain for hundreds and thousands of years. The isolation and counting of gas ions, on the one hand, which have crowned with success the long and brilliant researches of J. J. Thomson, and, on the other, the agreement of the Brownian movements with the requirements of the kinetic hypothesis, established by many investigators and most conclusively by J. Perrin, justify the most cautious scientist in now speaking of the experimental proof of the atomic structure of matter." When, therefore, even the foremost protagonist of the energetic school has come into the ranks of the atomists, there can now be little doubt that the evidence points to the reality of atoms and molecules, at least in the minds of those who are competent to judge. It may be added that much new evidence has accumulated since Ostwald wrote in 1908. We may, therefore, consider that the ground has been cleared of that type of obstructor who denies the existence of atoms other than as figments of the imagination.

In what follows I wish to present, for the benefit chiefly of those who have not had opportunity to follow the literature of the subject, a picture of the atom as we envisage it to-day. To do this most briefly, one can not in everything follow the historical development of the last thirty years. It is quicker, and often clearer, to give results first with supporting evidence afterwards, to employ a deductive as well as an inductive method.

THE PRESENT-DAY ATOM

Let me, therefore, say at once, and, for brevity, in a very didactic manner, that atoms are built up of two and only two kinds of building materials, bricks, or units of construction, namely protons and electrons. Under like conditions, all protons are alike and all electrons are alike. The chief attributes of these protons and electrons may be simply tabulated thus:

	MASS (AT REST)	ELECTRIC CHARGE	DIAMETER IN CM
Electron	1/1845	—1	3.8×10^{-13}
Proton	1	+1	2×10^{-16}

The hydrogen atom consists of one proton and one electron. The unit of mass here employed is a mass 1/1846th part less than that of the hydrogen atom itself. The precise value of this mass in grams does not here interest us any more than does the precise value of the unit electric charge expressed in terms of the conventional electrostatic units.

Every atom consists of a positively charged nucleus in which is concentrated nearly all the mass of the atom, and this nucleus is surrounded by a number of electrons sufficient to neutralize the nuclear charge. The atom as a whole is, of course, electrically neutral. For hydrogen, the positive nucleus consists of but one proton; but, in all other atoms, the positive nucleus contains what are called intranuclear electrons as well as protons. The value of the net positive charge on the nucleus of any particular type of atom is equal to the atomic number of the atom, that is, the ordinal number the atom would receive if all our 92 elements were numbered in order of increasing atomic weight, or, better, because of the three standard disorderly cases of potassium-argon, nickel-cobalt and iodine-tellurium, in order of rank in the periodic tabulation of the elements. The roll of the chemical elements, as we shall see, was called first, if incompletely, by one Moseley in 1914, and, of the 92 now on the roll, five elements are yet absent. The number of extranuclear or planetary electrons in chemical atoms, therefore, runs from 1 for hydrogen, 2 for helium, 3 for lithium, etc., up to 92 for uranium, the heaviest atom not yet extinct. The number of planetary electrons is the same as the atomic number of the atom.

The outside diameter of atoms is of the order of 1 to 5×10^{-8} cm., or 100,000 times the diameter of the electron, so that it is evident that the spacing of the nucleus and extranuclear electrons in an atom is a very open one, more so than in our solar system, in which, also, our central sun is inordinately large for true relative dimensions. So far as the volumes of the discrete structural units, pro-

tons and electrons, are concerned, therefore, atoms are filled chiefly with emptiness or void. Granting that the planetary electrons are so few in number, never over 92, and so light in weight, it is obvious that, as has been said, the main mass of the atom must be concentrated in its nucleus. To illustrate the make-up of an atomic nucleus, consider, for example, the case of the atom of fluorine. Its atomic weight is about 19. Therefore its nucleus must contain 19 protons, which would furnish a positive charge of +19. But its atomic number is 9, and hence its nuclear charge is +9. To reduce a positive charge of 19 to 9 will require the presence of 10 electrons in the nucleus, ten negative units of electrostatic charge thus offsetting ten of the positive units.

As regards the picture of the atom developed so far, there is much unanimity. The kind of questions not yet solved are those about the detailed constitution of the nucleus, and the arrangement of the extranuclear electrons. Further study might therefore be divided into (1) study of the nucleus and its constitution, and (2) study of the extranuclear portion of the atom and its possible arrangements of electrons, with the orbits or oscillations in which they are engaged. But we shall not follow this program.

Having placed before you a broad idea of the present-day conception of the structure of atoms, I wish now to go back and look at some of the methods of study that have led to the knowledge we have gained.

Electrons and Protons

Our knowledge of the electron has been reached chiefly through a study of the discharge of electricity through gases, with which the name of Sir J. J. Thomson is so closely associated. We should not forget, however, that, as early as the seventies of last century, Sir William Crookes observed streamers of light emerging from the cathode of highly evacuated discharge tubes. These he considered were composed of matter in a new, fourth state which he called "radiant matter." Certain German investigators thought the streamers were due rather to an ether wave motion analogous to light. It was not till 1895 that Sir J. J. Thomson showed that Crookes had been correct. The cathode rays are now known to consist of streams of swiftly moving electrons. Like any other particles that carry a charge, these electrons are deflected from a straight line course by either a magnetic or an electrostatic field properly applied, and, by using known field strengths of both kinds and measuring the resulting deflections of the electrons, the relation e/m between their charge and their mass can be ascertained. This is a method of measurement of very fundamental importance. Very high speed electrons of different, definite speeds are ejected

by certain "radioactive" atoms at the moment when such atoms break up, and a study of e/m for these electrons has shown that, if the charge is the same, the apparent mass increases with the measured speed of the electrons in a manner that harmonizes precisely with what would be anticipated on theoretical grounds if their mass were entirely what is called electromagnetic, or entirely due to their charge. Knowing that the mass of an electron is entirely electromagnetic in origin, we can then, assuming a spherical form, calculate by electromagnetic rules its radius, which comes out with the value noted above.

Individual electrons have been isolated by Millikan and others, and their charge evaluated precisely in electrostatic units. No electric charge that was a fractional part of that of an electron was ever encountered in this work, but only whole number multiples of it. From this it appears that negative electricity comes in small unit amounts or grains, like pepper. In other words, negative electricity, like matter, is atomic. At present we know less about the proton, or unit positive charge, than about the electron; its much greater mass, if electromagnetic, gives it a correspondingly smaller radius, as noted above, because, for the same charge on a spherical surface, electromagnetic mass varies inversely as the radius of the sphere.

Origin of X-Rays

The electrons in a discharge tube, such as an X-ray bulb, can be made to move with very high speeds, and so to carry much energy. They are stopped abruptly by striking the atoms that constitute the target in the bulb, and, by transferring some of their own energy, stimulate radiation of short wave light on the part of certain of the extranuclear electrons belonging to these atoms. They likewise themselves emit general wave radiation as they slow down. The very existence of these so-called X-rays, emerging from such targets, was not observed until 1896, and they were not known to consist merely of short wave length light until 1912.

X-Rays and Crystal Structure

I may remind you that one of the most successful methods of studying and analyzing common light is by means of a Rowland diffraction grating, which consists of a large number of fine lines ruled exceedingly closely together on a transparent or else reflecting surface. Such a grating will perform its analytical function only provided the ruling or grating space is sufficiently close compared with the wave length of the light being tested. A picket fence is a possible Rowland grating, but is far too coarse to give

useful results. So likewise a real Rowland grating is far too coarse to give appreciable diffraction of X-rays, because these are of such short wave length. In 1912 it occurred to the Swiss Laue that in ordinary crystalline substances we have ready-made very minutely spaced diffraction gratings, of skeletal type, indeed, and in three instead of only two dimensions of space. Stated otherwise, he thought the atoms of which the crystal is built might furnish centers to diffract the X-ray light, and these atoms are already arranged by Nature in rank, file and column with perfect regularity and with the requisite close spacing. Laue's expectations were brilliantly fulfilled, and the method has been developed by the Braggs in England, by Dr. Hull at Schenectady and by many others.

Because it is based on a relationship between the spacing of the layers of atoms and the wave length of the light diffracted by them, this powerful modern method of analysis may be employed in either of two ways, namely, to study (a) either the light wave length or (b) the spacing of the atoms. A single relationship connects these two unknowns. To get a value to start from, the atomic spacing in, say, sodium chloride can be computed from the known number and plausible crystallographic arrangement of atoms in one cubic centimeter of crystalline salt. Hence we can find the wave length of some particular easily-generated monochromatic X-ray light, which we can thenceforth use conveniently as our yard-stick in measuring atomic spacings in other crystals.

Results from the X-Ray Spectrometer

(a). Moseley in 1914 tried many different elements as targets in the X-ray bulb, analyzed the resulting X-rays by means of a crystal, and found that each element emitted general X-radiation, but also its own characteristic sets of X-rays of but a few kinds, that is, each element emitted a characteristic X-ray spectrum, consisting of but a few spectral lines peculiar to the element. Selecting a particular type of emitted light (K, L, etc., series) for making comparisons amongst the elements, Moseley arrived at the remarkable result that the square roots of the wave frequencies varied in progressive stepwise fashion from element to element, giving a series of equal whole-number steps that would, if complete, run approximately from 1 for hydrogen to 92 for uranium, just as the atomic numbers do. Any missing step was conspicuous, and indicated clearly an element lacking. From this we have learned that we must search for just five new elements, and that we must adjust our atomic numbers to allow for the elements that are missing.

It may here be remarked that the ordinary old style light spectra emitted by the chemical elements in the flame, arc, spark, sun or stars are of much more complex character than these simpler X-ray spectra. The latter give us information in regard to those extranuclear electrons which, after suffering displacement, gain positions of stability nearest to the nucleus; while the former longer wave light spectra inform us of the relatively slower radiations of those electrons that reach stations of stability in the outer regions of the atom. Within the last few years, both types of spectra have been so extended as to overlap, and the former outstanding gap of four octaves of light frequency has been completely bridged.

(b). The distances apart of layers of atoms in crystals are of an order smaller than one millionth of an inch. Small as are these distances, however, they are measurable by the X-ray spectrometer with an accuracy much better than one hundredth of one per cent. Given the crystallographic data of a crystal and its atomic arrangement, one may, by assuming the atomic weights of the constituent atoms, determine the density of the crystal by X-ray analysis with an accuracy superior to that of the more usual older methods. Conversely, if the density of the crystal is known, but the atomic weight of one of the constituent atoms is unknown, this may similarly be determined. Of greater interest, however, is the employment of the X-ray spectrometer to determine the arrangement of the atoms in a crystal. This can be done with a good deal of assurance for crystals belonging to the crystallographic systems of higher symmetry. Simple substances, such as the pure metals, usually crystallize in such systems, and have been subjects of fruitful study. Especially interesting to the organic chemist is the crystal lattice of diamond, in which each carbon atom is surrounded by four others at equal distances from it and in the directions of the four corners of a tetrahedron from its center of gravity. It has heretofore been tacitly assumed that the nuclei of the atoms in the crystal acted as simple point centers for diffracting light; but closer study reveals evidence of the position of certain extranuclear electrons which are in all probability those that constitute the valence bonds of the carbon. It is further apparent that these valence electrons, if not stationary, at least patrol stations other than the nucleus. This is confirmatory of the Lewis-Langmuir theory of atomic structure, to be mentioned shortly. Of even greater interest to the organic chemist are the recent studies by means of the X-ray spectrometer of the possible arrangement of the atoms in naphthalene, anthracene and allied substances. Viewed from one standpoint, the carbon atoms in

diamond lie at the corners of hexagons bent at their corners so as to fit on puckered surfaces, or surfaces composed of V-like corrugations like galvanized roofing without rounded bends. In spite of its different crystalline form, very different hardness, etc., graphite, the other crystalline form of carbon, exhibits an identical arrangement of carbon atoms in puckered hexagonal formation, but with the planes containing the hexagons further apart. Assumption of this same corrugated hexagonal structure, which appears so favorable for carbon atoms, satisfies the experimental results obtained with crystals of naphthalene in the X-ray spectrometer. One can not say that the organic chemist's customary graphic formula for naphthalene and its allies has been independently proved correct; but it has at least been shown that this time-honored formula is in complete harmony with the new experimental facts.

Arrangement of Extranuclear Electrons in Atoms

Passing from the arrangement of atoms in molecules to the arrangement of the extranuclear or planetary electrons in individual atoms, we reach a field where the experimental facts, chemical or spectroscopic, are more difficult of present interpretation, and where, at present, we are largely being guided and, I should add, stimulated by hypothesis. The hypothesis at present most acceptable to the chemist, doubtless because it was designed to fit the chemical rather than the spectroscopic facts, is that of Lewis and Langmuir; and this may be most easily visualized by the aid of models of atoms. Here we have the electrons patrolling definitely localized stations which are arranged in concentric shells round the nucleus. Similarity in number and arrangement of stations in the outermost shell makes for similarity of chemical properties, and so accounts for the well-known family resemblances of a chemical kind among the atoms. Furthermore, for many of the commoner atoms at least, the number of electrons in the outermost shell that gives the greatest stability is, on this "octet" theory, eight. If we personified such atoms, their chief ideal in life would be to secure, by hook or crook, an outside shell of precisely eight electrons; and this ideal motivates all the chemical reactions of such atoms. The two possible mechanisms by which the octet ideal is achieved are by reciprocal lending and borrowing or else by sharing electrons, corresponding to the conceptions of electrovalence and covalence, respectively. Atoms that already have eight electrons in their outer shells, like neon and argon, have no motive for any chemical action, and, as is well known, are entirely inert. By these new conceptions of valence, certain molecular structures are anticipated to be closely similar (isosteric) which

would be entirely dissimilar according to the older ideas of valence; and the close similarity of crystal form (isomorphism) actually observed in many such cases, a stumbling block and even a reproach to the chemical crystallographers of but ten years ago, strongly confirms the correctness of the newer views in these instances.

Less interested in the chemistry of the atoms, Bohr and his followers have been more concerned in devising an atomic model that will explain the kinds of energy radiated by an atom as light when one of its extranuclear electrons falls from a location of higher to one of lower potential energy, this light having a frequency which depends not on the final environment reached by the electron but rather on the energy made available by the fall. This theory is brilliantly successful, but hitherto only in the two simplest cases. If the planetary electrons all revolve in simple ellipses round the nucleus, there is insufficient localization of fields of force around the atom to satisfy the valence demands of the chemist, even although the orbits be not in the same plane. To me, the possibility of twisted or looped orbits round the nucleus would offer more satisfaction; as also would a complex electron to account for the facts of radiation.

Because both these types of hypothesis as to the arrangement and activities of the extranuclear electrons are at present in a somewhat speculative stage, I prefer to pass on to tell of other matters closer to the facts reached by the modern methods of study.

Spontaneous Disintegration of Atoms: Isotopes

All of our atoms of atomic weight over 206 are observed to have the proclivity to disintegrate. The nucleus of the atom of Uranium-1, for example, has a mass about 238 and a charge of +92. Occasionally, such an atomic nucleus, for cause utterly unknown, suffers a cataclysm in which the nucleus of a helium atom is expelled with enormous speed. (A helium atom consists of a minute nucleus built of 4 protons bound together by 2 electrons, which is surrounded by two planetary electrons). This expelled portion, endowed with terrific energy of motion, is called an alpha-particle. Because it lacks the two planetary electrons of the helium atom, it bears a double positive charge, and the moving alpha-particle can therefore be studied in the magnetic and electrostatic fields and the ratio measured of its charge to its mass, by which measurement its nature was divulged. On picking up two planetary electrons the alpha-particle becomes a helium atom. The precise volume has been measured of helium gas generated in this wise from radioactive material ejecting alpha-particles in numbers that can be counted one by one, and so has been enumerated directly

the number of helium atoms per cubic centimeter of the helium gas collected.

After throwing out its alpha-particle, the residual portion of the Uranium-1 atom, having lost 4 protons, possesses a mass 234 instead of 238. It has lost from its nucleus also 2 electrons, and therefore a net charge of (4—2) or +2. Its atomic number is thus smaller by 2, that is 90, and its ordinal position in the periodic table is two places below and to the left of Uranium-1. It is, in fact, a new element, named Uranium-X_1, which resembles the element Thorium. But it is a short-lived element, and soon expels from its nucleus an electron, or beta-particle, yielding a residual product, called Uranium-X_2, of the same atomic weight 234, but of atomic number 91. This disrupts with loss of another beta- particle even sooner than the last, producing the atom of an element, called Uranium-2, of atomic weight still 234, but of atomic number 92. But 92 is the atomic number of Uranium-1 from which we started. Thus Uranium-1 and Uranium-2 have the same nuclear charge, +92, and must have the same arrangement of extranuclear electrons, for this is ordered by the nuclear charge, and not appreciably by the nuclear mass. Thus, the outsides of U-1 and U-2 will be identical, and on the outside of an atom do its chemical properties depend. Consequently, U-1 and U-2, falling in the same ordinal position in the periodic system, are identical chemically and therefore inseparable by chemical means. Such elements are called isotopes. They have the same nuclear charge. Elements with the same nuclear mass are called isobars, as U-X_1, U-X_2, and U-2.

After a chain of successive disintegrations involving losses of 8 and 6 alpha-particles (mass 4) respectively, both uranium (mass 238) and thorium (mass 232) produce atoms with the nuclear charge of lead. On account of their different parentage, however, these two types of lead atoms would be expected to have masses of 206 and 208 respectively. They have each been isolated, from uranium and thorium minerals respectively, and found to possess atomic masses closely as expected.

Most of the known radioactive or spontaneously disintegrating elements have atomic weights of 206 or over. But rubidium and potassium are also radioactive, as are one of the constituents of common brass and also the metal platinum, although these latter atomic species disintegrate at an exceedingly slow speed and emit alpha-particles so lacking in energy that they are difficult to detect. There is no reason why the habit of disintegration should not be general among elements. In any case, we are clear that isotopic atoms, whether formed in a process of disintegration or in

a process of evolution, should be identical chemically, and so, like birds of a feather, should be found together. The question then arises, how many of our elements are mixtures of isotopes, indistinguishable by chemical difference? The question can be answered only by physical methods. If the isotopes are heterobaric, of different mass, then they can be identified and separated because of their difference in mass. Speed of diffusion or of free evaporation depends on mass, and so the elements mercury and chlorine have both been shown to consist of mixtures of heterobaric isotopes.

The Mass Spectrograph

But the most fertile method yet employed to recognize heterobaric isotopes is that devised by Sir J. J. Thomson, depending on the fundamental fact, already mentioned above, that different values of the ratio charge to mass of a charged particle moving in a high vacuum will give rise to different degrees of deflection in the magnetic and electrostatic fields. A gas or vapor particle containing the element under investigation is therefore given a positive charge in the discharge tube, and its resulting deflection is studied. Such a particle may acquire more than one unit charge, but such multiple charges cause no confusion. Refinement of this beautiful method in the hands chiefly of Aston has shown us that the elements Li, B, Ne, Mg, Si, Cl, A, K, Ca, Ni, Zn, Br, Kr, Rb, Sn, Xe, Hg, are all, at least as we have them ordinarily available on this planet, mixtures of isotopes; whereas H, He, Be, C, N, O, F, Na, P, As, I, and Cs have been studied and proved simple. Published results on no others are yet available. Only those elements which can readily be obtained in stable gaseous form have yet been investigated; but as soon as any of the less volatile elements or their compounds are obtained in suitable gas form, additional results of interest will be forthcoming. Because his measurements in the mass spectrograph of the masses of most atoms had an accuracy of 0.1 per cent., Aston was enabled to discover that the atomic weights of the chemical elements investigated, save hydrogen, are invariably whole numbers on the scale oxygen=16, to the degree of accuracy mentioned. The fractional value 35.46 found by chemical analysis for chlorine, for example, is explained by that element's consisting of certain proportions of two isotopes of masses 35.0 and 37.0 respectively. Thus is the century old hypothesis of Prout, that all atoms have masses that are whole number multiples of the mass of the hydrogen atom, resurrected and rehabilitated, but with a unit of mass almost 0.8 per cent. less than that of the hydrogen atom. Mathematical rigor in this "whole number rule" is, however, not to be expected for a reason that will now be referred to.

A New Possible Source of Cosmical Energy

Hydrogen, in Aston's mass spectrograph, appears to have an atomic mass of 1.008 (O=16), precisely as found by the chemists. Hydrogen, however, is unique among the elements in having no electrons but merely one proton in its nucleus. In all other atomic nuclei there are electrons packed close to the protons, and this close packing of charges of opposite sign is expected, by electrical theory, to influence the electromagnetic mass of the complex by an amount dependent on the closeness of packing. If we could build a helium atom from the materials which are correctly furnished by four hydrogen atoms, there would ensue a loss of mass of about 0.8 per cent., since the atomic weight of helium is 4.00. This mass, however, can not be destroyed, but must appear, according to the relativity theory, as an equivalent amount of energy. The quantity of energy concerned in the transformation of 1 gram of hydrogen to helium, namely 8 milligrams, or about the weight of one fifth of a postage stamp, corresponds to what, as electrical energy at ten cents per kilowatt hour, would cost $20,000.

If such a synthesis of helium from hydrogen may be supposed to be going on in the sun, we have a much needed explanation of the sun's present brightness at his known old age.

Experimental Utilizations of Alpha-particles in Investigation

The alpha-particles expelled from radioactive elements are by far the most energetic entities with which we are yet acquainted. The swifter kinds have, for unit mass, an energy of motion 400 million times greater than that of a rifle bullet. Being helium nuclei without circumambient planetary electrons, they are very small, and readily shoot through atoms, knocking out their extra-nuclear electrons right and left. The damaged atoms soon pick up other electrons to fill the gaps, and thus suffer no permanent change. Alpha-particles pass through thin glass, leaving no hole. Very occasionally, an alpha-particle will make a bullseye collision with the nucleus of an atom. The consequence of this collision, in the case of nuclei of some light atoms, is that the nucleus struck is disintegrated, with the expulsion of a single, swift-moving proton. The experiment succeeds in the case of B, N, F, Na, Al, and P nuclei. In the case of aluminium, Rutherford found that the single protons expelled have an energy of motion that is 40 per cent. greater than that of the alpha-particle missile that struck the atom. What remains of the aluminium nucleus is still under investigation, but it is permanently changed and is certainly no longer aluminium. Thus, in transmuting an element, we obtain free energy. The alchemists expressed this allegorically when they identified the philosopher's stone, which would transmute metals,

with the elixir of life, a source of ever fresh life or energy. Our enthusiasm for this transmutation is duly restrained by the knowledge that only about two per million alpha-particles make bullseyes on the aluminium nuclei.

In the case of the heavier atoms with their more highly charged nuclei, the alpha-particle, of the speed hitherto at our disposal, apparently loses too much energy in the approach to be able to effect disintegration of the nucleus. Its path is sometimes bent back in a large angle deflection, by an elaborate study of which in the case of gold the existence of the minute, positively charged nucleus of atoms was first established. The nuclear charges of gold, platinum, silver and copper have each been directly evaluated by this method, and agree with the atomic numbers of these atoms to 1 per cent., the known value of the experimental error.

The Duration and Possible Repetitions of Geological Time

The unchanging and, so far as all experiment goes, unchangeable spontaneous disintegration of heavy atomic nuclei has geological interests both in view of the time periods involved and also of the energy emitted in the process. Thorium disintegrates into thorium-lead, which is stable, at a rate which we have been able to ascertain. The "range" or distance travelled through matter by the expelled alpha-particles is strictly related to the rate of the various disintegrations, and such ranges and rates have ever remained constant for thorium and its descendants as evidenced by the constancy of the diameters of the range "halos" surrounding microscopic thorium inclusions in rocks of various ages. The diameters of these halos agree, also, with the ranges in air of the alpha-particles as studied to-day, and so the thorium clock has ever run at the same rate. Some thorium minerals contain lead whose measured atomic weight shows that it has practically all been derived from the decay of thorium atoms. From the ratio of the number of thorium atoms remaining to the number of those originally present, many of which are now represented by lead atoms which they produced, one can compute the age of the mineral, which thus gives a date to early paleozoic times of 150 million years back. Similar calculation from uranium minerals gives a period over 900 million years, but there is reason to believe that the uranium clock formerly ran fast, or, rather, that it appeared to run fast owing to the former presence of a third isotope of uranium, now almost extinct, of speedier rate of decay than what to-day we call U-1.

Rock analysis shows that, assuming percentage composition similar to that on the surface, there is enough radioactive material

in a depth of only 12 miles of the earth's crust to supply by its daily disintegration all the heat the earth radiates daily into space. If an appreciable amount of radioactive material exists below this depth, as seems certain, then heat must slowly be accumulating within the earth's non-conducting crust. Eventually, therefore, if no compensating heat-absorbing process is taking place within, an unstable state will be reached when the underlying incandescent material will perforce evert itself to the exterior and there disburden itself of its accumulated heat by radiation into space at a very rapid rate proportional to the fourth power of the temperature. This is the earth's incandescent epoch. When the crust has cooled down again sufficiently, a new geological epoch of perhaps 200 million years may begin, to be followed in turn by another incandescent epoch, and so on, alternately, but more and more slowly, until the radioactive materials, if not regenerated, have by disintegration lost their available energy. This alternation the Brahmans have symbolized in their cosmogony as the indrawing and outbreathing of the breath of Brahma.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By DR. EDWIN E. SLOSSON

Science Service

EVOLUTION WORKING BACKWARD

ONCE farmers planted the nubbins of their corn and the potatoes that were too small to sell. Now they know better. They cut up their finest potatoes to plant, and every grain of their seed corn is pedigreed as carefully as a Colonial Dame. The result is seen in the doubled yield in potatoes richer in starch and corn richer in protein. Modern agriculture is fertilized by science.

The most backward branch of biology is the infant science of sociology It is only just beginning to get its eyes open, to see things; in time, perhaps it will be able to do things, like the older sciences. But there is need of haste. The age of instinct is passing, the reign of reason has not come Man has been pushed up to his present position. He has succeeded in slackening the pressure. Will he go forward rationally, of his own free will, or sink back until again he falls under the sway of the blind and merciless forces of the struggle for existence?

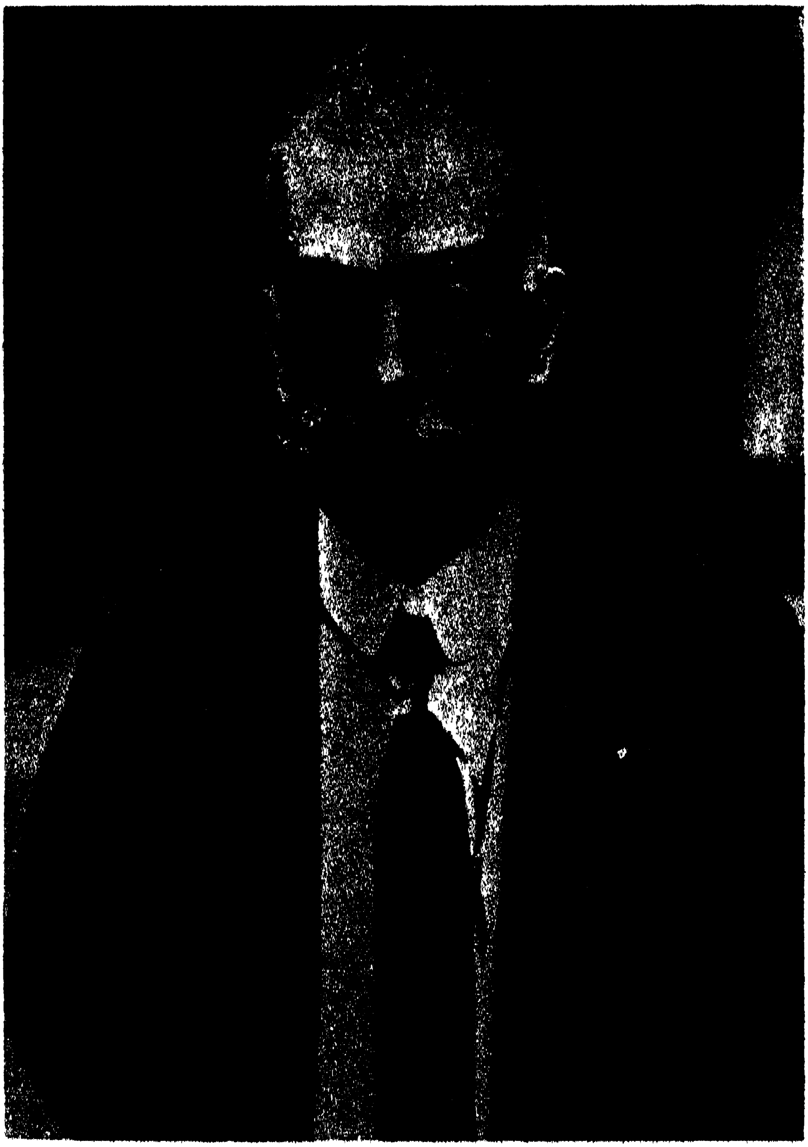
A decrease in the birth rate is not necessarily a misfortune to a country. Very likely, for instance, the British Isles have now all the population they can support in comfort under present economic conditions. The alarming thing about it is that the breeding is from the poorest stock instead of the best. Whatever objective standard one may take this is true. A statistical study of the population of Great Britain showed that in the districts where there was the most overcrowding, the cheapest type of labor, the lowest degree of culture and education, the highest percentage of pauperism and lunacy, the greatest criminality and the highest death rate from tuberculosis and infantile diseases, there the number of children was greatest in proportion to the possibly productive wives. It is a clear case of the survival of the unfittest, the reversal of evolution. No race can maintain its efficiency and virility against such reactive forces.

The future of a country depends ultimately upon the character and ability of its people. Increase of wealth, advance of science, improvement in education, discoveries in sanitation, juster social conditions, all the achievements and hopes of the present age will be of little benefit to posterity if there is a decline in the native quality of the race. It would be disastrous to hand over a more perfect and complicated governmental machine to inferior engineers. One seventh of the present generation will be the parents of one half of the next Therefore, two generations of selection, natural or designed, would completely transform the character of a nation. Is this seventh composed of the best men and women that we have?

This is what is going to determine whether civilization shall advance or retrograde. Galton's ideal of eugenics may be too much in advance of the age to be practical, but at least something could be done to awaken the people to the imminent dangers of dysgenics.

ATOMS OF LIGHT

THE discovery of the X-rays in 1895 acted like the discovery of gold in an unexplored country. It opened the way to the exploration of a field of unsuspected wealth of new knowledge and to the radical reconstruc-



Wide World Photos

PROFESSOR A. L. HERRARA

The distinguished biologist of Mexico, who is visiting the biological institutions of the United States.

tion of some of our time-honored and fundamental conceptions. It opened up to us the atom, the *ne plus ultra* of the chemist, and showed within it a system of revolving bodies far more numerous and complicated than the solar system. Already our knowledge of these electrons, whose existence was unsuspected a few years ago, is greater than our knowledge of the molecules, and we can study them with much more facility because they carry charges of electricity which betray their presence in the minutest number. A single electron can be detected while the smallest number of gas molecules which can be discerned with the spectroscope is about ten million million.

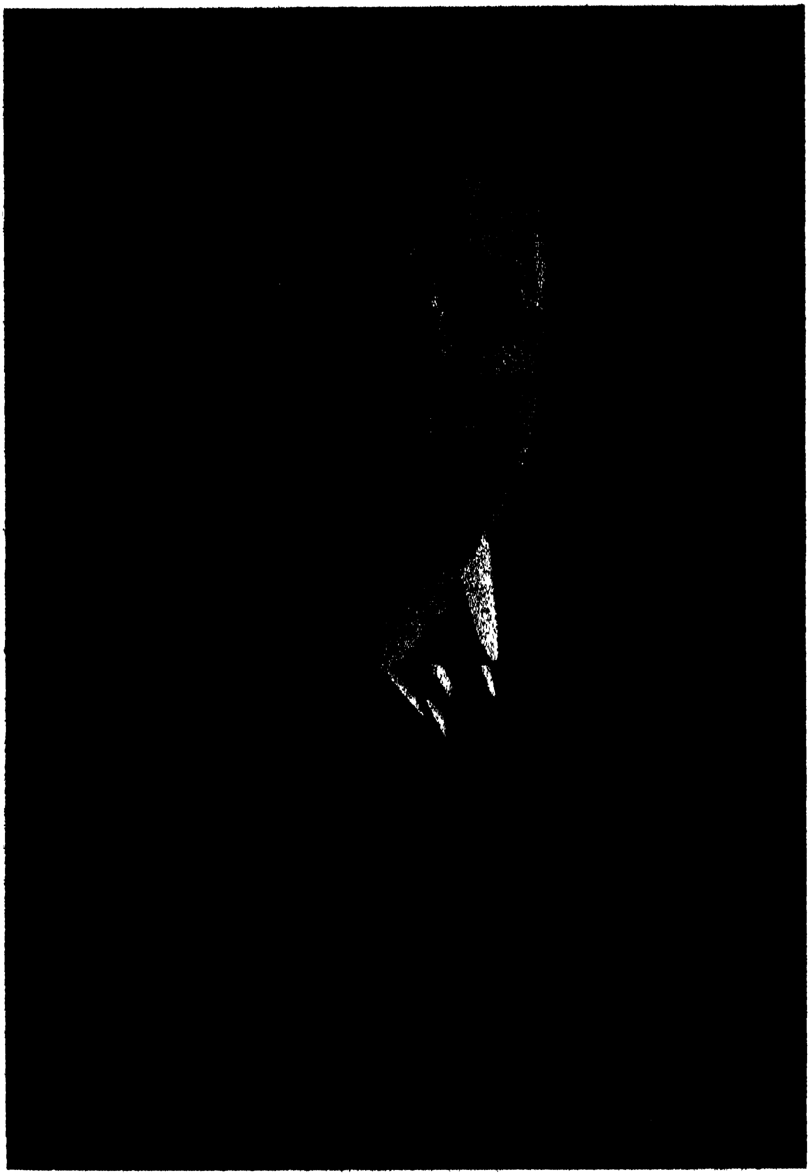
The tendency of the times is to extend the atomic theory into new fields, to speak of atoms of electricity, of energy and of light. The corpuscle, the smallest known particle of negative electricity, is only one seventeen-hundredth the mass of the atom of hydrogen. The smallest unit of positive electricity, on the other hand, seems to be equal to the atom of hydrogen. It is possible, however, that this positive particle may be a complex of many positive and negative particles and that the individual positive corpuscle when isolated as the negative one has been may prove to be equally minute.

The discovery of the enormous stores of energy compact in the atom in the form of the electrostatic potential energy of its negative corpuscles gives one a peculiar sensation. It is like finding out that there is a barrel of gold and a dynamite bomb in the cellar of the house. But a gram of hydrogen would be capable of developing more heat than the burning of thirty-five tons of coal. Since energy is wealth we have everywhere enough to make us all rich "beyond the dreams of avarice" forever, but we have no way of unlocking this storehouse. This may be fortunate for us since Professor J. J. Thomson, of Cambridge, says, "if at any time an appreciable fraction were to get free the earth would explode and become a gaseous nebula." Professor Thomson, in compensation for our natural disappointment at being frightened off these preserves by such a terrifying spring-gun, reminds us that on every sunny acre 7,000 horse-power of radiant energy from our solar dynamo is going to waste and that it is neither impossible nor dangerous to utilize it.

THE LITTLE ENEMIES OF MAN

Early in the history of the human race man learned how to conquer the mastodon. He has yet to learn how to master the microbe. Whales and elephants are now almost extinct, but mice and flies still increase and multiply, and the bacteria, smallest and most dangerous of all, find new ways of attacking us. It is only within the last few years that man has learned which his greatest enemies are, and he has not yet found weapons against them. The explorer in tropical jungles used to fear the lions, tigers and pythons; now he protects himself most carefully against the mosquitoes and tsetse. Mars has afflicted the human race less than Beelzebub.

Although we theoretically accept the conclusion of science that a man's foes are those of his own household, we are not yet aroused to the necessity of waging war in earnest against them. We have a secretary of navy and we give him millions for defense, but we have no secretary of sanitation, though that is a more necessary office. It is quite improbable that any American will be killed by an invading army this year, but our land is invaded by millions of mosquitoes and flies armed with deadly weapons and certain to slaughter thousands. Years of study and experimentation will be necessary before we learn how to fight our insect foes, but already enough has been done to show



Photograph by Harris and Ewing

DR. GEORGE P. MERRILL

Head curator of geology in the United States National Museum, to whom the National Academy of Sciences has awarded the J. Lawrence Smith Medal for his investigations of meteorites.

what can be accomplished if we go about it in the right way. Many of the sanitary measures of the past we now know to be crude, clumsy and misdirected, yet they are fixed in the popular mind and remain on our statute books. People still talk about the dangers of miasma and sewer gas, and think a deodorizer is a disinfectant.

We are far from acting up to our lights. The housewife wages war against vermin, but she does not realize that they are more dangerous than trolley cars. She gets more excited at the discovery of a moth than a fly, although the former only attacks clothing, not its contents. We have drain pipes in our walls to carry off disease, but beside them are conveniently arranged passages by which roaches can carry diseases from flat to flat, so that everybody has a fair chance to catch whatever is going Our windows are hospitably open to the malarial mosquito and typhoid-bearing fly. Over our clothing on the street cars crawl unmentionable insects carrying unmentionable diseases. In the fashionable hotel and restaurant the napery and porcelain are immaculate and the waiters are scrupulous; what goes on behind the screen and in the market is another story. We have got past the days when we kept the pig in the parlor, but we still keep the dog in the parlor, which is quite as bad. On the street we see the pet dog gnawing a decaying bone and nosing the foulest spot to be found, and a moment later he is cuddled in the arms of his fair and fastidious mistress and licking her cheek. We have yet to realize that it is the dogs which are not mad that are the more dangerous. They injure more people by their kisses than their bites.

In primitive days man had to associate with the lower animals. He needed dogs and horses and he very properly made friends of them. He is now learning how to do without them, and he should, like a snob who has risen in the world, exclude them from his circle of intimates. The house is not intended for a zoological garden. Insects and animals may be our worst enemies

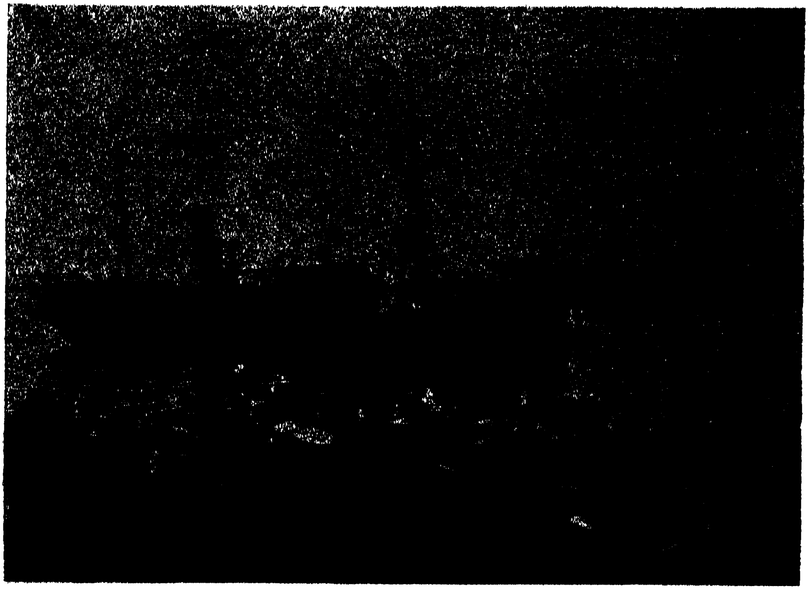
THE BIRTHPLACE OF THE EELS

THE final chapter in the life story of the eel has been written by the Danish expedition under Dr. Joh. Schmidt, which has recently returned to Copenhagen. The breeding grounds have been found between the Bermudas and the Leeward Islands, where the sea reaches a depth of more than a mile.

The origin and mode of reproduction of the common eel have been for centuries a matter of speculation. It has long been observed that large eels migrate toward the sea in autumn and that in the spring little elvers are found under stones on the seashore and ascend the streams in vast numbers. A group of small transparent salt water fishes, known as Leptocephali, were described in 1763, but no one guessed that they were in any way related to the eels.

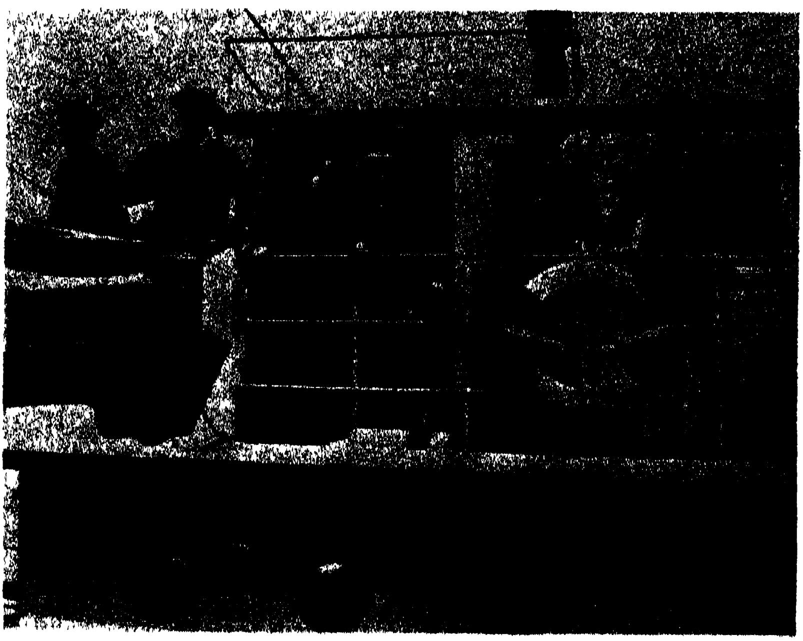
In 1864, Theo. N. Gill, of the Smithsonian Institution, published the conclusion that these Leptocephali are the young or larvæ of the eels, and this was confirmed through direct observation by Yves Delage in 1886. Beginning the following year, Professor Grassi made careful studies of the development of the eel in Sicily, observing the transformation of Leptocephali into the conger and other genera of eels, and in 1894 the larva of the common eel was discovered.

It was evident that the spawning of mature eels occurred in the sea, and now the place has been discovered by Dr. Schmidt. The European species deposit their eggs to the south and east of the Bermudas, while the American species breeds to the south and west of the islands.



Wide World Photos

The ship *Dana*, returning to Copenhagen with the Danish deep sea expedition which found the breeding place of the eel near the Bermudas.



Wide World Photos

The *Dana* at Elsinore, where it was boarded by Prince Valdemar of Denmark and Prince George of Greece, both of whom are seen in the door of the cabin, while the leader of the expedition, Dr. Johs. Schmidt, director of the Carlsberg Laboratory, is seen at the extreme left.

The former make a three-year migration to the shores of Europe from the North Sea to Italy, while the latter journey to the American coast from New England to the south in a few months or a year.

The Leptocephali after their transformation into elvers ascend the streams and sometimes travel overland from stream to stream or up the faces of dams and along the sides of rocks in search of sufficient water. The eels live for years in fresh waters, the period being from five to as many as twenty or thirty. In the autumn some of the mature eels travel back to the sea, the males then being from twelve to eighteen inches in length, the females never less than eighteen. At the original breeding places they spawn and die.

THE TOTAL SOLAR ECLIPSE OF SEPTEMBER 21

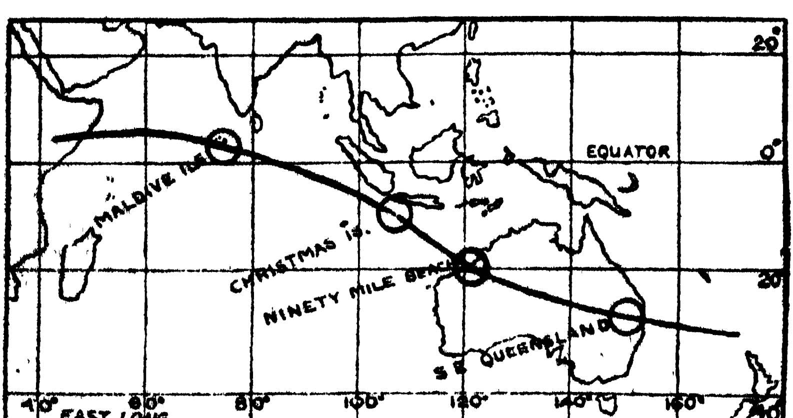
By Isabel M. Lewis

Science Service

Some of the points at which eclipse expeditions were located on September 21 are the Maldive Islands in the Indian Ocean, Christmas Island about 250 miles south of the west end of Java, Wallal on the western coast of Australia, Cordillo Downs in central Australia, to which instruments and supplies were transported by camel trains from Adelaide, South Australia and Goondiwindi in the southern part of Queensland. The longest duration of totality was five minutes and nineteen seconds at Wallal.

The Kodiakanal Observatory expedition from South India in charge of Director Evershed was in the Maldive Islands. On Christmas Island the eclipse was awaited by expeditions from the Royal Observatory of Greenwich and the combined expedition from Holland and Germany which were joined by observers from Java. The British expedition has been on the island since the last of March making extensive preparations for testing the Einstein theory of relativity. It is essential for this purpose to photograph the field of stars in which the sun will be found at the time of eclipse several months before or after the eclipse date. If, as the Einstein theory requires, the rays of light from stars near the sun are deflected from their course at the time of eclipse owing to the attraction of the sun's mass, a comparison of photographs taken when the sun is in this field of stars at eclipse with photographs taken several months previous when the sun was not in the field will show the displacement of the star images required by the theory.

A number of eclipse expeditions



From *Nature*.

Shadow track during total solar eclipse of September 21, 1922.

were located at Wallal, West Australia, owing to the generosity of the Australian government in placing at the disposal of the eclipse expeditions a transport of the Australian navy.

Some of the expeditions that accepted this offer of the Australian government are the Crocker eclipse expedition of the Lick Observatory, California, in charge of Professor W W Campbell; an expedition from the University of Toronto which included Dr. R. K. Young, of the Dominion Astrophysical Observatory, Victoria, B. C., and an expedition from the Observatory of Perth, West Australia. The transport left Freemantle, the port of Perth, the last of August and will bring members of the expeditions back to that port after the eclipse.

The chief object of several of the expeditions was to test the Einstein theory which requires that stars near the sun that are visible when the sun's rays are temporarily blotted out shall be displaced from their normal positions by amounts depending upon their angular distances from the rim of the sun. It will be recalled that the deflections both in direction and amount required by theory were obtained by the British observers at Principe, Africa, and Sobral, Brazil, at the time of the total solar eclipse of May, 1919. This is the first opportunity that has been afforded since that date to obtain an additional test of this prediction of the relativity theory.

SCIENTIFIC ITEMS

We record with regret the death of William S. Halsted, professor of surgery at the Johns Hopkins Medical School; of Rollin D. Salisbury, professor of geographical geology at the University of Chicago; of Dr. Harold C. Ernst, professor of bacteriology in the Harvard Medical School; of Stephen Smith, distinguished for his contributions to public health, who had nearly reached his hundredth birthday; of Arthur Ransome, the English authority on public health, who died at the age of ninety-two years; of W. H. Hudson, the English ornithologist and writer on natural history, and of Edward M. Eidheer, formerly expert in the Austrian bureau of chemistry.

The British Association for the Advancement of Science held its ninetieth annual meeting at Hull from September 6 to 13 under the presidency of Sir Charles Sherrington, professor of physiology at Oxford and president of the Royal Society. Professor Mangin, director of the Paris Museum of Natural History, presided over the meeting of the French Association for the Advancement of Science held at Montpellier from July 24 to 29 —The Association of German Scientific Men and Physicians held its hundredth meeting at Leipzig from September 18 to 24. One of the public addresses was by Professor Albert Einstein.

A prize of $25,000 to be awarded annually to a chemist of the United States for contributions to chemistry was announced by the Allied Chemical and Dye Corporation of New York, at the recent Pittsburgh meeting of the American Chemical Society.

The French Senate has unanimously voted 2,000,000 francs to observe the hundredth anniversary of the birth of Louis Pasteur, which will take place this year. The Senate in voting the appropriation described Pasteur as the "symbol of French science."

The late Prince of Monaco has bequeathed sums of one million francs each to the Academy of Sciences, the Academy of Medicine, the Institut Océanographique, the Institut de Paléontologie Humaine of Paris, and the Musée Océanographique of Monaco.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1922

SOCIAL LIFE AMONG THE INSECTS[1]

By Professor WILLIAM MORTON WHEELER

BUSSEY INSTITUTION, HARVARD UNIVERSITY

LECTURE IV—ANTS, THEIR DEVELOPMENT, CASTES, NESTING AND FEEDING HABITS

ON one occasion several years ago when I was about to lecture on ants in Brooklyn, a gentleman introduced me to the audience by quoting the sixth to eighth verses of the sixth chapter of Proverbs, and then proceeded in utter seriousness to give an intimate account of their author. He said that Solomon was the greatest biologist the Hebrews had produced, that he had several large and completely equipped laboratories in which he busied himself throughout his reign with intricate researches on ant behavior and that the 700 wives and 300 concubines mentioned in the Bible were really devoted graduate students, who collaborated with the king in his myrmecological investigations. The gentleman deplored the fact that the thousand and one monographs embodying their researches had been lost, and concluded by saying that he was delighted to introduce one who could supply the missing information. As he had consumed just forty-three minutes with his account of Solomon and his collaboratrices, I had to confess my inability to "deliver the goods" in the remaining seventeen. From what recondite sources of biblical exegesis the Brooklyn gentleman drew his information I have never been able to ascertain, but I am sure that Solomon's few myrmecological comments, which have come down to us from about 970 B. C., are very accurate—far more accurate than that story of Herodotus, written some 500 years later, of the gold-digging ants of India, which were as large as leopards, and whose hides were seen by Nearchus in the camp of Alexander the Great, and whose horns were mentioned by Pliny as hanging, even in his time, in the temple of Hercules at Erythræ.

[1] Lowell Lectures.

This and the many other ant stories invented or disseminated by ancient and modern writers are certainly not devoid of interest, but the actual behavior of the insect is so much more fascinating that you will pardon me for not dwelling on them.

The Formicidæ constitute the culminating group of the stinging Hymenoptera and have attracted many investigators for more than a century and especially during the past thirty years. Unlike the honeybee these insects make no appeal to our appetites nor even to that vague affection which we feel for most of the common denizens of our forests, fields and gardens, but only to our inquisitiveness and anxiety. Hence the vast literature which has been written on the ants may be said to have been prompted by scientific, philosophic or mere idle curiosity or by our instinct of self-preservation. In the presence of the ant we experience most vividly those peculiar feelings which are aroused also by many other insects, feelings of perplexity and apprehension, which Maeterlinck has endeavored to express in the following words: "The insect does not belong to our world. Other animals and even the plants, despite their mute lives and the great secrets they enfold, seem not to be such total strangers, for we still feel in them, notwithstanding all their peculiarities, a certain terrestrial fraternity. They may astonish or even amaze us at times, but they do not completely upset our calculations. Something in the insects, however, seems to be alien to the habits, morals and psychology of our globe, as if it had come from some other planet, more monstrous, more energetic, more insensate, more atrocious, more infernal than our own. With whatever authority, with whatever fecundity, unequalled here below, the insect seizes on life, we fail to accustom ourselves to the thought that it is an expression of that Nature whose privileged offspring we claim to be. . . . No doubt, in this astonishment and failure to comprehend, we are beset with an indefinable, profound and instinctive uneasiness, inspired by beings so incomparably better armed and endowed than ourselves, concentrations of energy and activity in which we divine our most mysterious foes, the rivals of our last hours and perhaps our successors. . . ."

The similarities which the ants, as one of several families of aculeate or stinging Hymenoptera, necessarily bear to the wasps and bees, are so overlaid by elaborate specialization and idiosyncrasies that their primitive vespine characters are not very easily detected. I wish to dwell on some of these specializations, but before doing so, it will be advisable to give under separate captions a brief summary of what I conceive to be the fundamental peculiarities of the ants:

(1) The whole family Formicidæ consists of social insects, that is, it includes no solitary nor subsocial forms such as we found among the beetles, wasps and bees. We are therefore unable to point to any existing insects that might represent stages leading up to the social life of the ants. Within the family, nevertheless, we can distinguish quite a number of stages in a gradual evolution of social conditions from very simple, primitive forms, whose colonies consist of only a few dozen individuals, with a comparatively feeble caste development, to highly specialized forms with huge colonies, comprising hundreds of thousands of individuals and an elaborate differentiation of castes.

(2) The number of described species of ants is approximately 3,500, but if we include their subspecies and varieties, many of which will probably be raised to specific rank by future, less conservative generations of entomologists, we shall have more than double the number. This is far in excess of the number of all other social insects, including both the groups I have already considered and the termites. The ants are therefore the dominant social insects.

(3) This dominance is shown also by their geographical distribution, which is world-wide. There are ants everywhere on the land-masses of the globe, except in high arctic and antarctic latitudes and on the summits of the higher mountains. The number of individual ants is probably greater than that of all other insects. With few exceptions, the termites are all confined to tropical or subtropical countries, and the number of social wasps and bees in temperate regions is very small.

(4) We found that the social wasps arose from the Eumenine solitary wasps and the bees from the solitary Sphecoids. All the authorities agree that the ants had their origin in neither of these ancestral stocks, but among the Scolioids, a distinct offshoot of the primitive Vespoids. Of the four modern families of the Scolioids, the Psammocharidæ, Thynnidæ, Mutillidæ and Scoliidæ, the last seems to be most closely related to the ants. Since they must be traced to ancestors which were winged in both sexes, the Thynnids and Mutillids, which have wingless females, are excluded, and the family Psammocharidæ is not very closely allied to the Formicidæ.

(5) The ants, unlike the social wasps and bees, are eminently terrestrial insects. They inherited and seem very early to have exaggerated the terrestrial habits of their primitive Scolioid ancestors. The majority of the species in all parts of the world still nest in the soil. Many of them later took to nesting in dead or decaying wood, and more recently a number of species, especially in the rain-forests of the tropics, have become arboreal and nest by preference in the twigs of trees and bushes or construct paper or

silken nests among the leaves and branches. The terrestrial habit led to a permanent phylogenetic suppression of the wings in the workers, an ontogenetic loss of the wings in the queens and a diminution of the eyes in both of these castes. A few very archaic ants still possess large eyes like the wasps and bees, but in the great majority of species, which are more or less subterranean, and therefore practically cave-animals during much of their lives, the eyes have dwindled, and in many species have almost or completely disappeared. The great abundance of ants in the desert, savanna and prairie regions of the globe indicates that they arose during some period of the Mesozoic, perhaps during the Triassic or Liassic, when the climate was warm but arid. Their extensive adaptation to low, damp jungles, with their rank vegetation, seems to have developed during the Cretaceous or early Tertiary. The ants therefore resemble the solitary wasps, which are still conspicuously abundant in hot, arid regions. Both groups are represented by only a small number of species in cool, moist regions, like New Zealand, the British Isles and certain mountain ranges, like the Selkirks of British America.

(6) In the social wasps and bees we found that the worker,

FIG 54

Stigmatomma pallipes, a primitive, subterranean Ponerine ant of the United States The winged individuals are virgin queens and are very similar to the workers Nearly twice natural size. (Photograph by J. G. Hubbard and O. S Strong.)

or sterile caste, though distinctly differentiated, is, nevertheless, very much like the queen, or fertile female. In ants the differences are much greater. Even when, as in many primitive ants (Fig. 54), the worker resembles the queen in size and form, it never possesses wings, and in most ants the two castes are so dissimilar that they have often been described as separate species. The male ant, too, is much less like the queen than is the corresponding sex among the social wasps and bees (Fig. 57). It is evident, therefore, that all three castes are more highly specialized. In many ants, as we shall see, the worker, queen and male may each become differentiated into two or more castes, a phenomenon which is nowhere even suggested among the wasps and bees.

(7) Very long and intimate contact with the soil has made the ants singularly plastic in their nesting habits. While most social wasps and bees construct elaborate combs with very regular, hexagonal cells of such expensive substances as paper and wax, the ants merely make more or less irregular galleries or chambers in the soil or dead wood or if they construct paper or silken nests avoid a rigid type of architecture. Hence the great variability of nesting habit in the same species. This plasticity and saving of time and labor are very advantageous, because they enable the insects, when conditions of temperature or moisture become unfavorable or when bothersome enemies settle too near the nest, to change their habitation readily and without serious loss to the colony. Espinas long ago noticed the importance of the terrestrial habits of ants. He says: "Ants owe their superiority to their terrestrial life. This assertion may seem paradoxical, but consider the exceptional advantages afforded by a terrestrial compared with an aërial medium in the development of their intellectual faculties! In the air there are the long flights without obstacles, the vertiginous journeys far from real bodies, the instability, the wandering about, the endless forgetfulness of things and of oneself. On the earth, on the contrary, there is not a movement that is not a contact and does not yield precise information, not a journey that fails to leave some reminiscence; and as these journeys are determinate, it is inevitable that a portion of the ground incessantly traversed should be registered, together with its resources and its dangers, in the animal's imagination. Thus there results a closer and much more direct communication with the external world. To employ matter, moreover, is easier for a terrestrial than an aërial animal. When it is necessary to build, the latter must, like the bee, either secrete the substance of its nest or seek it at a distance, as does the bee when she collects propolis, or the wasp when she gathers material for her paper. The terrestrial animal has its building materials close at hand, and its architecture may be as

varied as these materials. Ants, therefore, probably owe their social and industrial superiority to their habitat."

(8) The plasticity of ants is shown even more clearly in their care of their young, which are not reared in separate cells but in clusters and lie freely in the chambers and galleries of the nest where they can be moved about and easily carried away or hidden when the colony is disturbed or the moisture and temperature conditions are unfavorable. Like their continual contact with their physical environment, their intimate acquaintance with their young in all their stages has been an important factor in the high psychological development of the Formicidæ.

(9) A similar plasticity characterizes their feeding habits. As a group they feed on an extraordinary range of substances: the bodies and secretions of other insects, seeds, delicate fungi, nectar, the saccharine excréta of plant-lice, scale insects, etc. Some species seem to be almost omnivorous.

(10) All this adaptability, or plasticity in nesting and feeding habits is, of course, an expression of a very active and enterprising disposition and has resulted in the formation of a vast and intricate series of relationships between ants and other organisms, including man. These restless, indefatigable, inquisitive busybodies, forever patrolling the soil and the vegetation in search of food, poke their noses, so to speak, into the private affairs of every living thing in their environment. Nor do they stop at this; they actually draw many organisms, by domesticating them or at any rate attaching them to their nests or bodies, into the vortex of their ceaseless, impudent activities. Nearly every week during the past twenty years I have received from some entomologist somewhere on our planet one or more vials of ants with a request for their identification, often because they had been found associated with some insect or plant which the sender happened to be investigating. In the next lecture I shall describe a number of the strange partnerships into which ants have entered as a result of their inordinate and unappeasable appetites.

As my time is limited I shall select for discussion only a few of the topics suggested in the foregoing summary, namely, the main taxonomic divisions of the family Formicidæ, polymorphism, or the development of castes, the origin and growth of colonies, the structure of the alimentary canal in adult and larval ants and the evolution of the feeding habits.

In their main outlines, at least, the phylogenetic relationships of the various subdivisions or subfamilies of the Formicidæ have been clearly established. There are seven of them: the Ponerinæ, Cerapachyinæ, Dorylinæ, Pseudomyrminæ, Myrmicinæ, Dolicho-

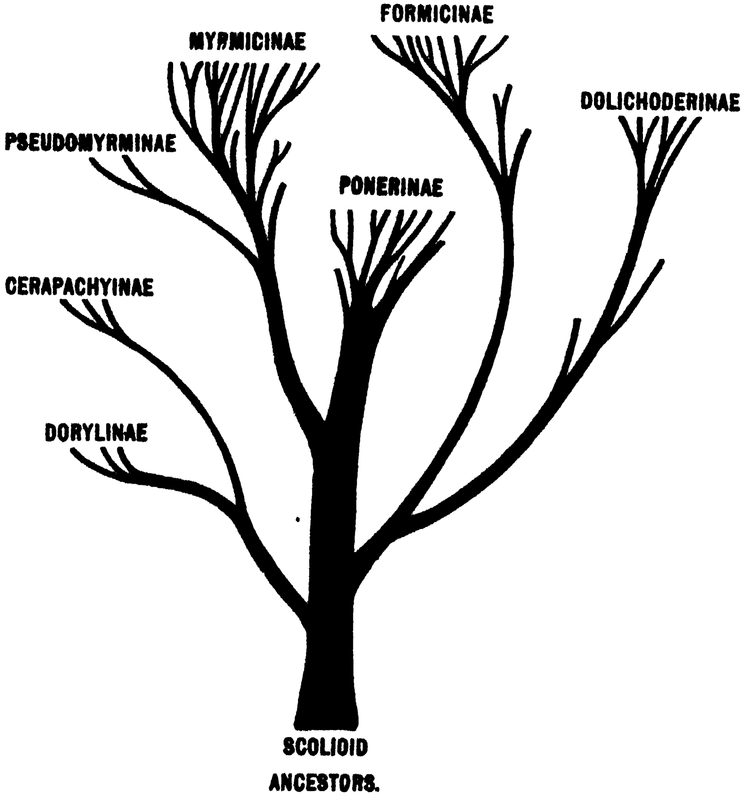


FIG. 55
Ancestral tree showing the putative phylogenetic relations of the family Formicidæ as a whole and of its subfamilies to one another

derinæ and Formicinæ. The Ponerinæ constitute the primitive, basic stock of the family and have given rise to the six other subfamilies, which are represented in the ancestral tree (Fig. 55) as so many branches. Their thickness roughly indicates their vigor or comparative development and their height their degree of specialization and dominance in the existing fauna. All the subfamilies are well represented in the tropics of both hemispheres, but in the north temperate region nearly all the species belong to the two largest and highest subfamilies, the Myrmicinæ and Formicinæ. In temperate North America and Eurasia there are very few Dolichoderinæ and Ponerinæ and no Cerapachyinæ nor Pseudomyrminæ. A small number of Dorylinæ extend as far north as Colorado, Missouri and North Carolina (35° to 40°) and to about the same latitude on the southern shores of the Mediterranean.

With the exception of a series of peculiar parasitic genera, which are represented only by males and females, all ants possess a sharply defined worker caste. In primitive groups, like the

Ponerinæ, Cerapachyinæ and Pseudomyrminæ, the worker is nearly as large as the queen but lacks the wings and has therefore a more simply constructed thorax, the compound eyes are smaller and the simple eyes or ocelli are minute or absent. In the three subfamilies mentioned the worker is monomorphic, that is, it always has the same form though it may vary somewhat in size. In the four remaining subfamilies (Dorylinæ, Myrmicinæ, Dolichoderinæ and Formicinæ) we find the same uniformity of the worker in many species, but in a considerable number it has become highly variable, or polymorphic, as a result of agencies which have acted independently in each subfamily or even within the limits of a single genus (Figs. 57 and 58). In such cases the workers can be arranged in a graduated series, beginning with large, huge-headed individuals more like the queen in stature, and ending with minute, small-headed individuals, which may be very much smaller than the queen. Such a series exhibits not only great morpholog-

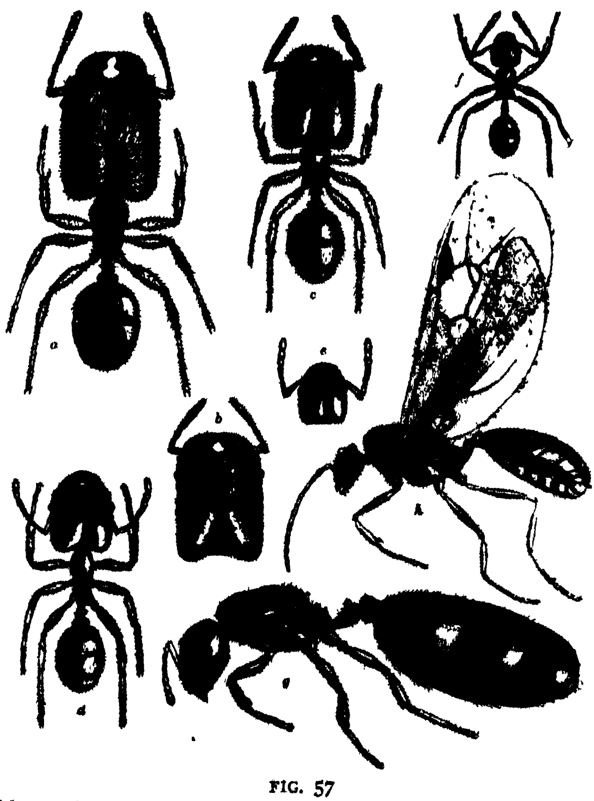


FIG. 57

A small Myrmicine harvesting ant of Texas, *Pheidole instabilis*, with polymorphic worker caste. *a*, soldier, *f*, worker; *b* to *e*, forms intermediate between the soldier and worker (lacking in most other species of the huge genus Pheidole); *g*, queen (deälated); *h*, male. The figures are all drawn to the same scale.

FIG. 58

Portion of a colony of a common Formicine ant (*Camponotus americanus*), comprising virgin, winged queens and workers, the latter showing the unstable polymorphism in stature and size of head, characteristic of most species of the genus. (Photograph by J. G. Hubbard and O. S. Strong.)

ical but also great functional differences among its members. The largest individuals commonly act as policemen or defenders of the colony, but in some species their powerful jaws enable them to crush seeds or the hard parts of insects, so that the softer parts may be exposed and eaten by the smaller individuals (Fig. 57). The latter excavate the nest, forage for food, nurse the young and in some species devote all their energies to the cultivation of the fungus gardens. In a graduated series like the one described we usually call the largest workers "maximæ," the smallest "minimæ" and the intermediate forms "mediæ," the word "operariæ" (workers) being understood in each case. Now in some ants only the two extremes, the maximæ and the minimæ, of the polymorphic series proved to be serviceable to the colony, so that all the intermediate forms (mediæ) have been eliminated, leaving the worker caste distinctly dimorphic. In such ants we call the maximæ "soldiers" (*milites*) and the minimæ "workers" (*operariæ*). This condition has been attained in several genera and subgenera among the Myrmicinæ and Formicinæ (Pheidole (Fig. 57), Oligomyrmex, Colobopsis, etc.). In still other genera,

where soldiers were not needed or were too expensive to rear and maintain, on account of their great size and appetites, they too have been eliminated and the worker caste is represented only by the tiniest individuals of the originally polymorphic series (Carebara, Tranopelta, Pædalgus, Solenopsis, etc.). There is therefore an enormous difference in these ants in size and structure between the queen and the only surviving worker form of the species. In Carebara, *e. g.*, the queen is several thousand times as large as the worker! Nevertheless, both are merely extreme female forms of the same species and may, of course, develop from the eggs of the same mother.

But the worker is not the only caste that has become dimorphic. In some species there are two distinct forms of queen, in others two distinct forms of male. In these cases one of the forms is winged, the other usually apterous. And here again, by suppression of the winged female or winged male, the wingless form may become the only surviving fertile form of its sex in the species. All these developments are interesting because they indicate that the distinctions among the various castes have arisen gradually by continuous or fluctuating variations and that the survival and persistence of some of them and the elimination of others have led to the sharply discontinuous series of castes which we find in many ants.

It is obvious that some of the differences between the various castes, especially those in size, are due to differences in the amount of food consumed during the larval stages, but the profounder morphological differences which separate the queens, soldiers and workers, must be due to other causes. We must suppose either that the food administered to the larvæ differs in quality or that there are several different kinds of eggs, some of which develop into fertile, other into sterile forms. In a sense the latter would be mutations, like the various sterile forms of the evening primrose, which make their appearance generation after generation from some of the seeds of the fertile forms. In the case of the ants, however, we find that the workers not infrequently lay viable eggs, and though they are never fertilized and generally develop into males, the latter may mate with queens and thus be a means of establishing a representation of the characters of their worker mothers in the germ-plasm of the species. The peculiar anomalies known as gynandromorphs, that is, individuals partly male and partly female, which occasionally occur among ants, also indicate that the queens, soldiers and workers arise from as many different kinds of eggs, since there are three different kinds of gynandromorphs, exhibiting respectively combinations or mosaics of male and queen, male and soldier and male and worker characters. It

is difficult to see how such perfectly definite combinations could be produced by larval feeding, and it is equally difficult to account for them as the results of internal secretions. In the present state of our knowledge we can only surmise that the differences between the queen and worker castes were originally ontogenetic and determined by feeding, as they still are in the social wasps and bees, but that in the ants the germ-plasm has somehow been reached and modified, so that an hereditary basis for caste differentiation has been established.

The ant colony may be initiated and developed by one of two different methods which I shall call the independent and the dependent. The former is peculiar to the nonparasitic, the latter to the parasitic species. Leaving an account of the ants which employ the dependent method for the next lecture, I would say that the great majority of ants establish their colonies in essentially the same manner as Vespa and the bumble-bees. The winged, virgin queen, after fecundation during her nuptial flight, descends to the ground, rids herself of her wings and seeks out some small cavity under a stone or piece of bark, or excavates a small cell in the soil. She then closes the opening of the cell and remains a voluntary prisoner for weeks or even months while the eggs are growing in her ovaries. The loss of the wings has a peculiar effect on the voluminous wing-muscles in her thorax, causing them to break down and dissolve in the blood plasma. Their substance is carried by the circulation to the ovaries and utilized in building up the yolk of the eggs. As soon as the eggs mature, they are laid and the queen nurses the hatching larvæ and feeds them with her saliva till they pupate. Since she never leaves the cell during all this time and has access to no food, except the fat she stored in her abdomen during her larval life and her dissolved wing-muscles, the workers that emerge from the pupæ are all abnormally small. They are, in fact, always minimæ in species which have a polymorphic worker caste. They dig their way out through the soil, thus establishing a communication between the cell and the outside world, collect food for themselves and their mother and thus enable her to lay more eggs. They take charge of the second brood of eggs and larvæ, which, being more abundantly fed, develop into larger workers. The population of the colony now increases rapidly, new chambers and galleries are added to the nest and the queen devotes herself to digesting the food received from the workers and to laying more eggs. In the course of a few years numerous males and queens are reared and on some meteorologically favorable day the fertile forms from all the nests of the same species over a wide expanse of country escape simultaneously into the air and celebrate their marriage flight. This flight provides

not only for the mating of the sexes but also for the dissemination of the species, since the daughter queens, on descending to the ground, usually establish their nests at some distance from the parental colony.

It will be seen that the queen ant, like the queen wasp and bumble-bee, but unlike the queen honeybee, is the perfect female of her species, possessing not only great fecundity but in addition all the worker propensities, as shown by her ability to make a nest and bring up her young. But as soon as the first brood of workers appears, these propensities are no longer manifested. That they are not lost is shown by the simple experiment of removing the queen's first brood of workers. Then, provided she be fed or have a sufficient store of food in her body, she will at once proceed to bring up another brood in the same manner as the first, although she would have manifested no such behavior under normal conditions.

As already stated, this independent method of colony formation is the most universal and is followed alike by tropical and extratropical ants. It is undoubtedly the primitive method and, as we shall see, the one from which the dependent method has been derived. It differs from that of Vespa and Bombus, nevertheless, in leading to the formation of perennial colonies even in temperate and boreal regions. The queen ant may, in fact, live from 12 to 17 years and although, like other aculeates, she is fecundated only once, may produce offspring up to the time of her death. Unlike the queen honeybee she is never hostile to her own queen daughters, and in many species of ants some of these daughters may return after their marriage flight to the maternal colony and take a very active part in increasing its population. In this manner the colony may become polygynic or pleometrotic, and in some instances may contain a large number of fertile queens. When such a colony grows too large it may separate into several, the queens emigrating singly or in small companies, each accompanied by a detachment of workers, to form a new nest near the parental formicary. This behavior is exhibited by the well-known mound-building ant (*Formica exsectoides*) of our New England hills. You will notice that its mounds usually occur in loose groups or clusters and that the workers of the different nests are on friendly terms with one another and sometimes visit back and forth. We may, of course, call the whole cluster a single (polydomous) colony, but it really differs from a number of colonies only in the absence of hostility between the inhabitants of the different mounds. In certain tropical ants, like the Dorylinæ (Figs. 59 and 60), however, I am inclined to believe that the only method of colony formation is by a splitting of the original colony into as many parts as it con-

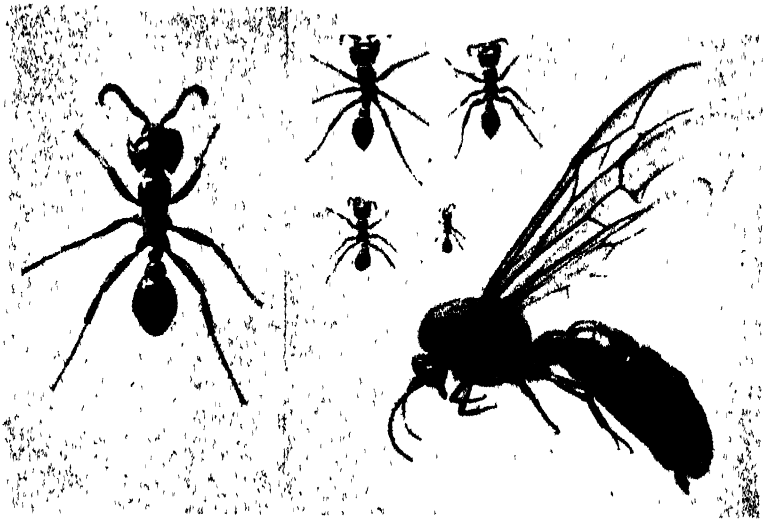


FIG. 59
Argentinian legionary (Dorylinc) ant *Eciton* (*Acamatus*) *strobeli*. Workers showing polymorphism and male, photographed to the same scale as the four smaller workers. (Photograph by Dr Carlos Bruch.)

FIG. 60
Dorsal and lateral view of the wingless queen (dichthadiigyne) of *Eciton* (*Acamatus*) *strobeli*. Same scale as Fig. 59. (Photograph by Dr. Carlos Bruch.)

tains young queens. These huge, clumsy creatures (Fig. 60) are always wingless and must therefore be fecundated in the nest, and since the colonies, which comprise hundreds of thousands of workers, are nomadic and keep wandering from place to place, they must become independent entities as soon as they are formed.

We possess no accurate data on the age that ant colonies may attain. Some of them certainly persist for 30 or 40 years and probably even longer. In such old colonies the original queen has, of course, been replaced by successive generations of queens, that is, by her fertile daughters, grand-daughters and great-grand-daughters, and the worker personnel has been replaced at a more rapid rate, because the individual worker does not live more, and in most instances lives considerably less, than three or four years.

The feeding habits of ants are so varied and complicated that it will be advisable before considering them to describe the structure of the alimentary canal in both adult and larva. The mouth-parts of the adult are of the generalized vespine type and consist

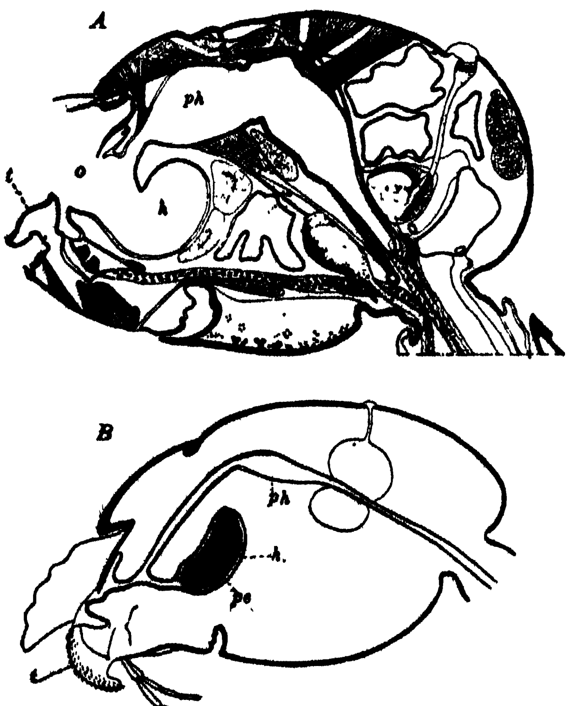


FIG. 61

Sagittal sections through the heads of ants. A, of queen *Lasius niger* with the mouth open (After Janet). B, of queen *Camponotus brutus* with the mouth closed. *t*, tongue; *o*, oral orifice; *ph*, pharynx; *h*, infrabuccal pocket; *pe*, pellet *in situ*, made up of solid particles of food refuse and strigil sweepings. Note stratification in the substance of the pellet, indicating successive meals or toilet operations.

of a small, flap-like upper lip, or labrum, a pair of strong, usually toothed mandibles, a pair of small maxillæ and a broad lower lip, or labium. The maxillæ and labium are each provided with a pair of jointed, sensory appendages, the palpi. The mandibles, which are really the ant's hands, vary greatly in shape in different genera and are used not only in securing the food but also in many other activities, such as digging in the earth or wood, transporting other ants or the young, fighting, leaping, etc. Liquids are, of course, merely imbibed and swallowed, but solid food is seized and crushed with the mandibles and the juices or smaller particles licked up with the tongue, which is a roughened pad at the tip of the lower lip (Fig. 61*t*) just anterior to the opening of the duct of the salivary glands. The small particles thus collected are carried back into a small chamber or sac, the infrabuccal pocket (Fig. 61*h*), which lies immediately below and anteriorly to the mouth-opening (*o*). This pocket is an important structure since it serves as a receptacle not only for the more solid particles of food but also for the dirt, fungus-spores, etc., which the ant collects during her toilet operations, for the ant is an exquisitely cleanly insect and devotes much of her leisure to licking and burnishing her own smooth or finely chiseled armor and that of her nest-mates. Moreover, the tip of the fore tibia is furnished with a beautiful comb or strigil which can be opposed to another comb on the concave inner surface of the fore metatarsus. The ant cleans her legs and antennæ by drawing them between these combs, which are then drawn across the mouth, with the result that any adhering dirt is carried off into the infrabuccal pocket. In this manner the dirt and the solid or semisolid food particles are combined and the whole mass moulded in the infrabuccal pocket into the form of a roundish oblong pellet (Fig. 61*B pe*). After any liquid which it may contain has been dissolved out and sucked back into the mouth, the pellet is cast out, so that no solid food actually enters the alimentary canal. All adult ants therefore subsist entirely on liquids.

The alimentary canal proper is a long tube extending through the body and divided into sections, each with its special function. The more anterior sections are the mouth cavity, the pharynx (Fig. 61 *ph*), which receives the ducts of certain glands, and the very long, slender gullet, which traverses the posterior part of the head, the whole thorax and the narrow waist, or pedicel of the abdomen as far as the base of its large, swollen portion, the gaster. Here the gullet expands into a thin-walled, distensible sac, the crop, which is used for the storage of the imbibed liquids. At its posterior end the crop is separated from the ellipsoidal stomach by a peculiar valvular constriction, the proventriculus. The hindermost sections of the alimentary tract are the intestine and

the large, pear-shaped rectum. The crop, proventriculus and stomach are the most interesting of these various organs. Forel calls the crop the "social stomach," because its liquid contents are in great part distributed by regurgitation to the other members of the colony and because only a small portion, which is permitted to pass back through the proventricular valve and enter the stomach, is absorbed and utilized by the individual ant. That the crop functions in the manner described can be readily demonstrated by permitting some pale yellow worker ant to gorge herself with syrup stained blue or red with an aniline dye. The ant's gaster will gradually become vividly colored as the crop expands. Now if the insect be allowed to return to the nest, other workers will come up to it, beg for food with rapidly vibrating antennæ and protrude their tongues, and very soon their crops, too, will become visible through the translucent gastric integument as they fill with the stained syrup. Then these workers in turn will distribute the food by regurgitation in the same manner till every member of the colony has at least a minute share of the blue or red cropful of the first worker.

The alimentary tract of the helpless, legless, soft-bodied ant grub or larva is much simpler than that of the adult. The mouth-parts are similar but more rudimentary. As a rule, the mandibles are less developed but in some larvæ they are strong, dentate and very sharp. The lower lip is fleshy and protrusible and provided with sensory papillæ instead of palpi, and the unpaired duct of the long, tubular and more or less branched salivary glands opens near its tip. The mouth-opening is broad and its lining in many species is provided with numerous transverse ridges beset with very minutes spinules (Fig. 62*C*). Larger, pointed projections or imbrications may also cover the basal portions of the mandibles. All these spinules and projections are probably used in triturating the food but perhaps when rubbed on one another they may also produce shrill sounds for the purpose of apprising the worker nurses of the hunger or discomfort of their charges. The gullet is long and very slender and opens directly into the large stomach, which throughout larval life is closed behind, that is, does not open into the intestine. A communication with the more posterior portion of the alimentary tract is not established till the larva is about to pupate. Then all the undigested food which has accumulated in the stomach since the very beginning of larval life is voided as a large black pellet, the meconium.

In the larvæ of the Pseudomyrminæ (Figs. 62, 63 and 64) there are certain very peculiar additional structures which may be briefly described. The head is not at the anterior end of the body as in other ant larvæ but pushed far back on the ventral surface so that it is surrounded by a great hood formed from the three thoracic

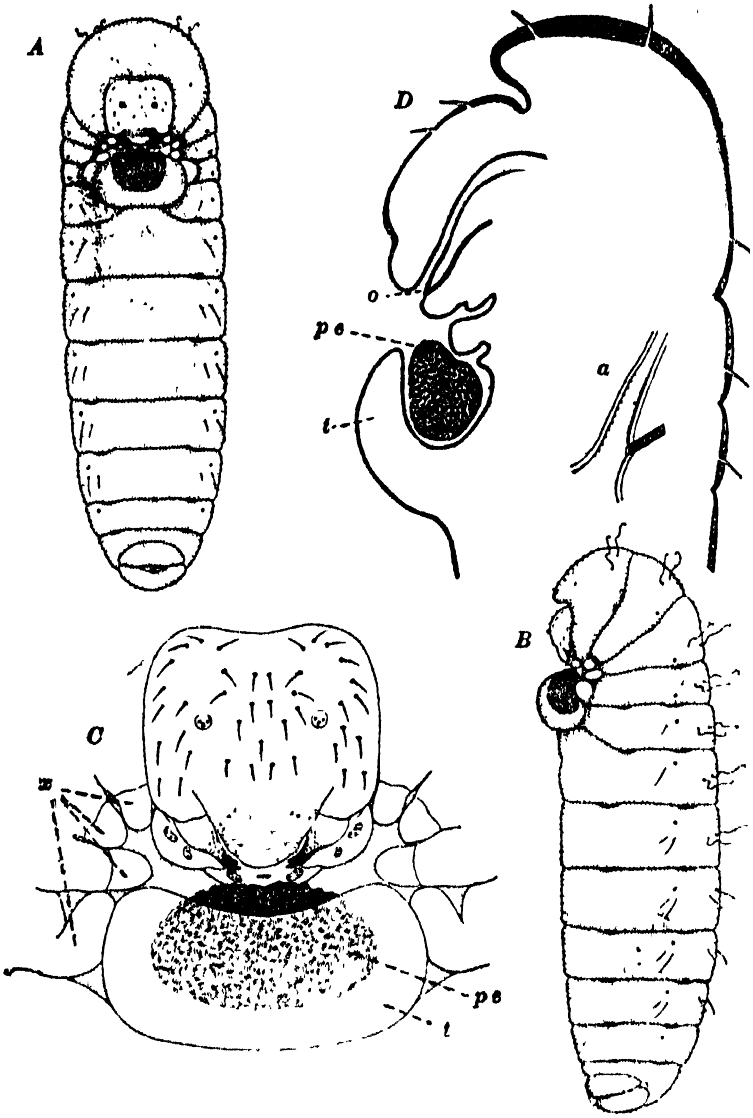


FIG 62

Larva of *Pseudomyrma gracilis*. *A*, ventral, *B*, lateral view; *C*, head and adjacent portions of same enlarged; *D*, sagittal section through anterior portion of larva. *o*, oral orifice; *x*, exudatoria; *t*, trophothylax, or pocket, which holds the pellet; (*pe*), deposited by the worker nurses and which is eaten by the larva. Note the hooked dorsal hairs of the larva, which serve to suspend it from the walls of the nest. *a*, mouth cavity, more enlarged to show the fine spinules (also seen in *C*), which serve to triturate the pellet and probably also as a stridulatory organ

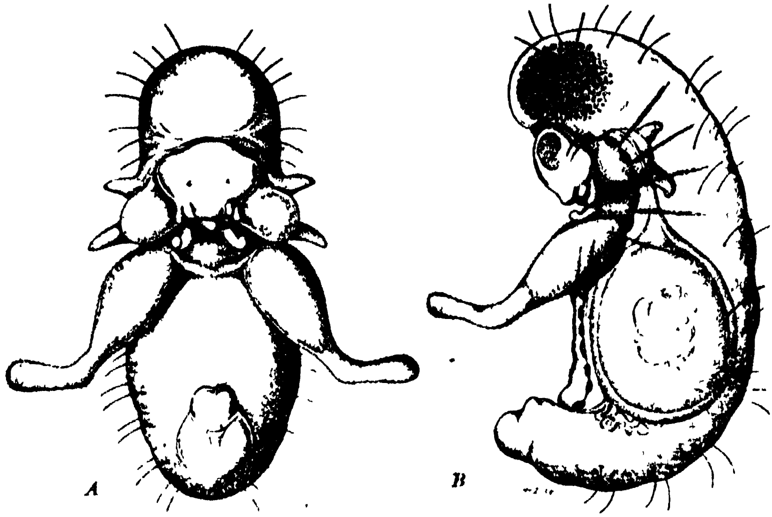


FIG 63
A, ventral, *B*, lateral view of the first larval stage ("trophidium") of the Ethiopian *Pachysima latifrons*, showing the peculiar appendages ("exudatoria") surrounding the head These belong to the three thoracic and the first abdominal segments

segments, and the first abdominal segment, which lies immediately behind the head, has in the midventral line a singular pocket, the trophothylax (*t*). Furthermore, each side of this segment and each ventrolateral portion of the several thoracic segments is developed as a peculiar protuberance or appendage, which functions as a blood-gland, or exudatorium (*x*).

Unlike the adult ants the larvæ can devour solid food, though they are often fed, at least in their youngest stages, with liquids regurgitated on their mouths by the worker nurses. The larvæ of the Pseudomyrminæ are fed with the pellets (*pe*) from the infrabuccal pocket, which are placed by the workers in the trophothylax where they are within easy reach of the mandibles and can be gradually drawn into the mouth, triturated and swallowed. Some primitive ants (Ponerinæ, some Myrmicinæ, etc.) actually feed their young with pieces of insects or entire small insects, which are simply placed on the ventral surface of the larva within reach of its mouth-parts.

In a former lecture I referred to the fact that the larvæ of the social wasps, either before or after feeding, produce droplets of a sweet salivary secretion, which are eagerly imbibed by the adult wasps, and I designated this interchange of food between adult and larva as trophallaxis. I have recently made some observations which show that the ant larvæ also produce secretions which appeal to the appetites of their nurses. These secretions are more varied than in the wasps. Certain ant larvæ undoubtedly

supply their nurses with saliva, but many or all sweat a fatty secretion through the delicate general integument of the body, and the larval Pseudomyrminæ produce similar exudates from the papillæ or appendages above described. Although these various substances are produced in very small quantities they are of such qualities that they are eagerly sought by the adult ants. This explains much of the behavior which has been attributed to maternal affection on the part of the queen and the workers, such as the continual licking and fondling of the larvæ, the ferocity with which they are defended and the solicitude with which they are removed when the nest is disturbed. In other words, a decidedly egoistic appetite, and not a purely altruistic maternal anxiety for the welfare of the young constitutes the potent "drive" that initiates and sustains the intimate relations of the adult ants to the larvæ, just as the mutual regurgitation of food initiates and sustains the similar relations among the adult workers themselves.

I am convinced that trophallaxis will prove to be the key to an understanding not only of the behavior I have briefly outlined

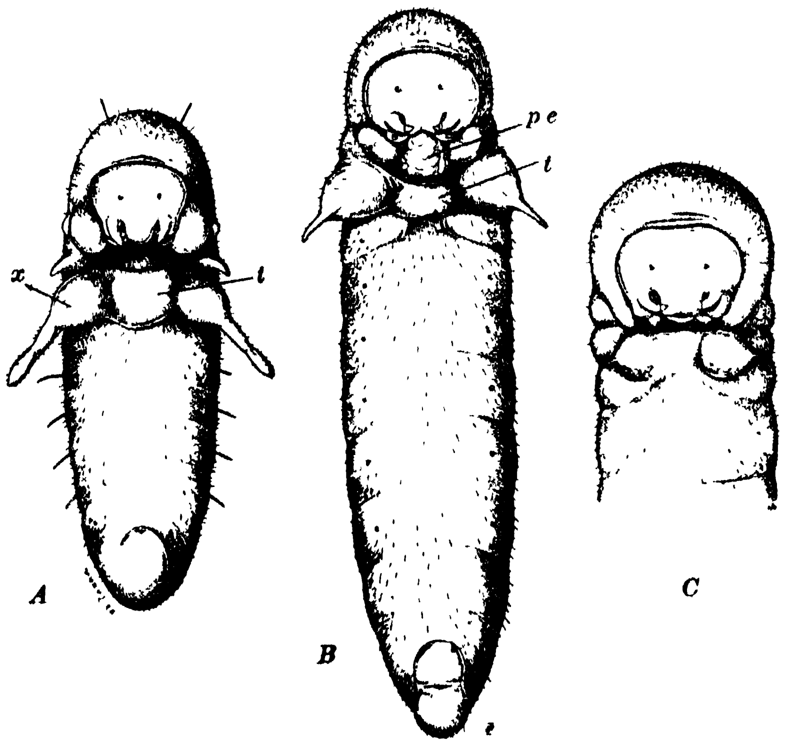


FIG. 64
Second, third and fourth (adult) larval stages of Pachysima latifrons, showing the gradual dwindling of the exudatoria. *A* and *B* show the trophothylax (*t*); and *B* also shows the food pellet *pe*, which is the pellet formed in the infrabuccal pocket of the worker nurse, *x*, exudatorium. See Figs. 62 and 63.

but also of the relations which ants have acquired to many kinds of alien organisms. In the accompanying diagram (Fig. 65) I have endeavored to indicate how trophallaxis, originally developed as a mutual trophic relation between the queen ant and her brood, has expanded with the growth of the colony, like an ever-widening vortex, till it involves, first, all the adults as well as the brood

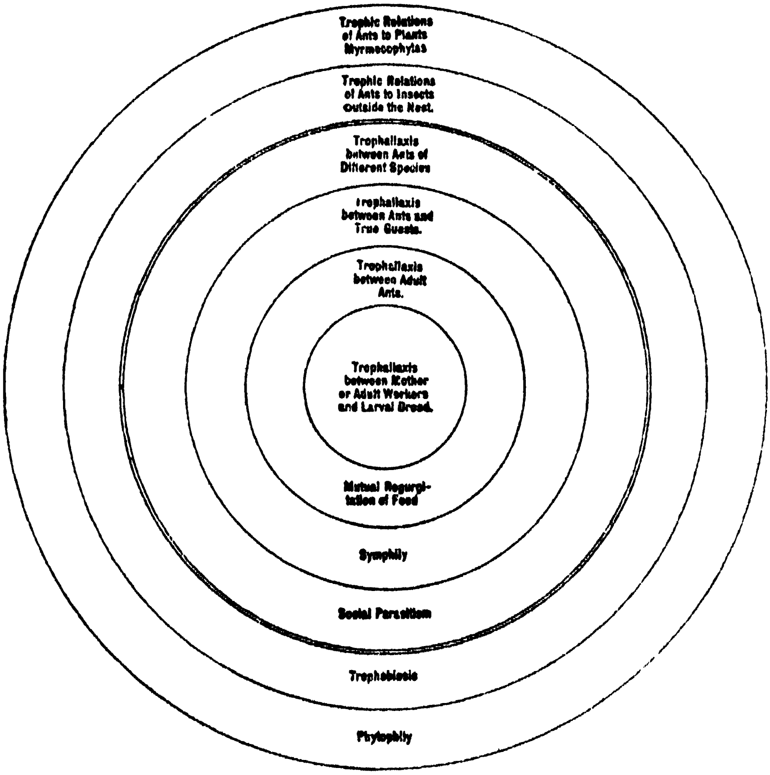


FIG. 65
See text for explanation.

and therefore the entire colony; second, a great number of alien insects that have managed to get a foot-hold in the nest as scavengers, predators and parasites (symphiles); third, alien social insects, that is, other species of ants (social parasites); fourth alien insects that live outside the nest and are "milked" by the ants (trophobionts), and fifth, certain plants that are regularly visited or even inhabited by the ants (myrmecophytes). These extranidal relationships, represented by the two outer rings in the diagram are, of course, incomplete or one-sided, since the organisms which they represent are not fed but merely cared for or protected by the ants. In my next lecture I shall have more to say about some of these relationships.

(To be continued)

WATER[1]

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THE task of science is one that may be fulfilled quite directly by providing useful information of a practical sort for our immediate needs, or it may furnish us with general ideas which, if we are skilful enough and intelligent enough, we may use to explain a great variety of phenomena. These general ideas when combined make up our conception of the universe. The latter function of science is the more important one. It is the one that brings science close to philosophy. It is the one that arouses the greatest interest and enthusiasm in those who pursue the task of science. When we look for generalizations of this kind we always seek simple explanations of nature, confident that they may be used as guides to our action in particular cases and as means for gaining an ever increasing control of the world that we live in. Everything in the history of science justifies us in saying that it is the general interpretation of nature which, especially in the last hundred years, has given man his extraordinary increase in material power, an increase in power which he has used far from wisely no doubt, but which for better or for worse he possesses.

In the ancient world there were a certain number of advances of this kind. The history of geometry, in spite of the labors of the last century and in spite of Einstein, is to a great extent ancient history. The few necessary general conceptions that the Greeks found out enabled them to develop a complete science of geometry, enabled them to be good surveyors, enabled them to begin to understand how to lay out the heavens and the earth in their astronomy and in their geography, enabled them to see how to make buildings, and to do a great many practical things.

But in the main the really important, the really general ideas of science, are modern, and of course the most interesting ones have to do, at least so most people will think, not with static things, not with space taken by itself, but with dynamic things, with the question of what is happening in the world. On the whole, the most interesting and the most important generalizations of science

[1] This lecture was one of the public series given in Boston on Sunday afternoons recently under the auspices of the Harvard Medical School.

will be judged by most men to be those that tell them what is happening in the world, how things happen and how those happenings may be, if possible, changed to their own advantage, and how they may be interpreted so as to yield a philosophy.

Of course everyone knows that the first step in this direction in modern times, the first step of great importance, was the interpretation of the phenomena of our solar system. It was the labors of Copernicus, of Galileo, and of Newton that enabled men to look at the sun and the moon and the planets, and to think quite clearly and quite simply and without any sort of difficulty at all about what their movements and their apparent changes in position and in form indicated. But, once more, it is not so much our solar system as it is our own earth that interests us, and until we come down to the earth and examine the happenings on the surface of the earth we are necessarily a long way from those things that interest us most.

How shall we state abstractly what is happening on the earth? That is one of the great questions for science as well as for philosophy, for sociology, and for all the other intellectual activities of man. What is happening on the earth? Of course there are an indefinite number of answers to that question; but if we seek the strictly scientific answer of physical science I think there can be very little doubt that it is possible to put it in a few words which make our interpretation of the changes in nature surrounding us surprisingly simpler than they otherwise would be.

Men in antiquity and in all ages have vaguely perceived an answer to this question. Perhaps many of you have heard of the famous remark of Thales, who is often thought of as the founder of philosophy and mathematics and science, that water is the origin of all things. This statement seems to many people to-day, I suppose, ridiculous, or at all events very exaggerated, but it is in fact much less ridiculous and much less exaggerated than you may suppose. A little later Empedocles and Aristotle, extending the elements from one to four, included water along with earth, air, and fire as the elements of which the world is made up. No doubt the word "element" is used in a sense a little different from our ordinary idea of an element to-day, but we still speak of the Aristotlean idea when we talk about exposure to the elements. Of these elements water is in many respects the most interesting. Nevertheless, while it was always clear in antiquity, as it has been in modern times, that water is very important in the world that surrounds us, its real importance is a comparatively recent discovery.

In the first place, it was only a century and a half ago when

Cavendish and Watt and others first found out that water is not itself what the chemist now calls an element, but that it is a compound, a compound of hydrogen with oxygen, a substance that can be formed by burning hydrogen gas in air or in oxygen. With this discovery a new road was opened, not only for chemistry and for physiology, but for the general interpretation of nature. Even before that time men had begun to understand the meteorological cycle, to perceive that there is going on on the earth a physical process which may be very briefly described as the evaporation of water from the ocean, from lakes and streams, and from the moist land, its dissemination as water vapor throughout the atmosphere by the winds, its precipitation as rain and snow and hail and dew, its collection into streams, but not a rapid collection, for it persists for long periods of time in the soil and underground, and finally its return to the ocean and reevaporation. That had been perceived, as I say, quite clearly before the discovery of the chemical nature of water.

After that discovery another thing became apparent, that all that is happening in living organisms, in animals, and in plants on the earth, may be regarded in one sense as a part of this great meteorological cycle, this great cycle of water in its evaporation and condensation and flowing back through definite channels; for, as you know, our rivers persist, our streams persist, the circulation takes place in a very definite and very definitely canalized way. As I say, when men had made out the chemical nature of water they were able to see that water and carbonic acid are taken up by the plant, taken, if you will, out of the meteorological cycle and built up into sugar and starch, and then, sooner or later, turned into a great variety of substances, the substance of the plant, in short. These in turn serve as the food of the herbivorous animals, of cattle and sheep, and they are not greatly modified when built up into the body of the ox or the sheep. Next they may be consumed by man, or by a carnivorous animal, and are made over into the materials of his body. But sooner or later they are turned out into inorganic nature, excreted, as water and carbonic acid, after being burned in the body, once more to become a part of the meteorological cycle.

That, I submit to you, is a fair statement, which no doubt needs a great deal of enlargement, a fair statement in terms of physics and chemistry, of what is happening on the surface of the earth. What is happening on the surface of the earth is, first of all, a circulation of water, a circulation of water which we recognize in the fall of rain, in the flow of streams, which we recognize equally in the growth of plants and in the feeding of animals on plants,

and in the burning up of material in the body of the animal—of course a circulation of water and of other things, other things which in the total are very numerous and certainly very difficult to know in all cases, but fundamentally a circulation of water.

I have not touched upon the energy of the process, the side of the question that is represented by the energy that goes into the water to evaporate it off the surface of the ocean, that goes into the green leaf to turn water and carbonic acid into sugar and starch, or the energy that comes out again in the form of muscular activity and body heat in you as you live, when you convert starch, sugar, and other things formed from them in the plant, back to water and carbonic acid. But let us say in the beginning that what is happening on the surface of the earth is this circulation of water, and let us add that it is a circulation which is driven by the energy of the sun, which is driven both in the one cycle, in the meteorological cycle, by the sun's heat evaporating the water, and in the other, the organic cycle, by the sun's energy making possible the formation of sugar and starch from water and carbonic acid.

In the first place, this process depends upon the great amount of water that there is on the earth. There is enough, if the earth had a perfectly smooth surface, to cover the whole earth, to a depth of two to three miles. How much of this is circulating it is very difficult to say. The amount is large. For instance, at the Equator evaporation takes off a layer of perhaps about seven feet every year from the tropical ocean. Of course the evaporation is less in other localities, and it is much less where there are no great bodies of water, but that will perhaps give you some idea of the magnitude of the process.

How much is the energy involved in this process? How much work is done? How much energy of the sun does it take to evaporate so much water? A few square miles of the tropical ocean are taking up solar energy in the process of the evaporation of water to such an extent that if that energy were available in the bodies of the people of the United States, it would run all their bodies; that is to say, all the work that we are capable of doing, plus all the heat that we produce, is equivalent to an amount of energy which is no greater than that involved in evaporating the water off a very few, perhaps ten, square miles of the surface of the tropical ocean. So you see that not only is there a vast amount of water being evaporated, but that amount of water carries with it, involves in its evaporation, a prodigious amount of energy.

Another way of studying the process is to try to form an idea of the run-off of the rivers of the earth. It has been estimated that the run-off is yearly, for all the rivers of the earth, about 6,500

cubic miles of water; that is to say, if you were to take a band a little more than two miles wide from Boston to San Francisco, and imagine it to rise up one mile into the air, that would give you a solid equivalent to the volume of water that pours back into the oceans yearly. And that of course is only a fraction of the water that evaporates yearly, because a great deal that evaporates and falls to the ground never reaches the ocean at all.

This prodigious amount of water carries with it to the ocean what seems to be an almost equally prodigious amount of other material. There are something like 5,000,000,000 tons of dissolved substance in the river waters going back to the ocean yearly, and nobody knows how much undissolved sediment there may be. This dissolved material has been leached out of the earth, it is being leached out of the earth all the time, and the record of it is the accumulation of dissolved substances in the ocean as well as that long continued action of sedimentation which is on the whole the greatest of geological processes.

In the sea, as a result of this, nearly all the chemical elements are contained in solution, most of them, to be sure, in such small amounts that they can not be measured, but so many of them are there that the sea water is quite a different thing from anything else in the world, and can not be imitated. Nobody ever made an artificial sea water that would serve the purposes of sea water as an environment for simple marine forms, as well as sea water itself. You may make as careful an analysis as you please of the sea water. You may put into pure distilled water all the things that you can find in the sea water, and then if you try to make organisms live there they will not live in it—some of them, at least, will not—as well as they will live in genuine sea water.

There is a good deal of resemblance between the salts dissolved in our blood and the salts dissolved in sea water. This has led Quinton to speculate about the use of sea water for medical purposes. He has made many experiments by diluting it to the proper degree and injecting it into the body. It has been suggested by Professor MacCallum that our blood is, so to speak, descended from sea water, that in the course of evolution somehow or other the fluids of the body originated as sea water. Of course single-celled organisms have no blood. When multi-cellular beings came into existence, where did the fluid which bathes the cells come from, provided multi-cellular individuals did develop from the unicellular? It is not a wild assumption to suppose that sea water furnished the inter-cellular liquid, that it was the material that first surrounded the several cells making up the complex organism. If you look into the whole story of comparative physiology that

idea, while it must not be pushed too far, seems not an extravagant one, and if so, it is interesting to reflect that in that original simple fluid, simple compared with our blood in most respects, there were nevertheless a vast number of substances that had been leached out of the earth's crust in the course of millions of years.

This peculiarity of sea water depends upon the fact that water is, among all the liquids that we know, on the whole the best solvent, the one that can dissolve the greatest number and the greatest variety of substances of all kinds. That of course is a statistical statement. There are some things that water can not dissolve which can be dissolved by a great many other things; but by and large, taking everything that we know, taking all the chemical substances that we know, there is not anything which on the whole is a better solvent, or capable of dissolving a larger number of things, or greater quantities of them, than water.

Well, that is one of the very decisive facts in the meteorological cycle. It is one of the great factors in determining the geological action of water, in determining a large part of the evolution of the surface of the earth. And, on the other hand, in the organic cycle, in men, in animals, and in plants, water, always present in large quantities—your own body is three quarters water—contains a great number of things dissolved in it. This solvent action is certainly no less important in physiology than it is in geology.

Not only does the water in your bodies, the water in the blood, the water inside the cells, the water in the lymph, contain a great many things dissolved in it, but it is almost exclusively in solution that things penetrate into your body. That of course may seem to you a strange statement. You are well aware that you eat many more or less solid substances—anybody can swallow a lump of sugar, which is certainly a solid—but in fact what is geometrically inside your body is not necessarily physiologically inside your body. The digestive tube is physiologically not inside the body, and the process of digestion turns most substances that are swallowed in solid form into soluble products, which are dissolved in water and then in solution pass the real physiological barrier, the wall of the intestine, and so enter the body. This is no less true of the substances that are excreted from the body. The waste products are turned out of the body in solution, and if it were not possible to turn them out in solution it is very difficult to imagine by what kind of physiological device it would be possible to carry on the activities of really active bodies and get rid of the waste products that have been burned up in the course of their activity.

This great circulation of water has another very important influence upon the world, and upon the world of life, and that is

its effect upon climate. Every one knows how much more steady is the state of the weather on small islands at great distances from continents than in most other places. Every one knows how much milder the climate is, how much cooler in summer and warmer in winter, at the sea shore than a comparatively small number of miles inland. This phenomenon depends upon water.

How does it depend upon water? What is the effect that water exerts in that respect? Well, there are several factors. In the first place, it takes a great deal of heat to raise the temperature of water, or, as the physicist says, the specific heat of water is high. If you take, for instance, a pound of water and a pound of almost anything else—there are a few substances that are harder to heat than water—and heat them over a carefully regulated flame for a certain length of time, and measure the rise in temperature, you will find that the rise in temperature of the water is less than that of the other substance. As I say, there are a few exceptions, but there are very few. The result is that an ocean or a lake absorbs heat, and does not itself rise very much in temperature.

Again, the evaporation of water takes up heat. Every one knows that. Every one knows that in order to evaporate water away at all rapidly you must heat it, and the amount of heat that is taken up in this evaporation of water is greater than in the evaporation of anything else; that is to say, you have got to put more heat into water in order to boil away or to evaporate, let us say, a pound of it, than you have in order to evaporate a pound of anything else. Thus the more rapid the evaporation the more effective the resistance of water to the rise of temperature, and for that reason the cooler the climate in the marine region compared with the climate in a region where there is no water to evaporate. This is one of the most important of all economic factors on the earth. It is a factor that, as much as any other one, perhaps, determines whether a given part of the earth is or is not really favorable for a high and active and prosperous civilization.

But these factors are no less important in your own body than they are in determining the climate. As you know, you are constantly producing a considerable amount of heat, and that heat has somehow or other to be got rid of. If it were not, your body temperature would continue to rise. Well, in the first place, if your body were not mostly water, and therefore such that it takes a great deal of heat to raise its temperature one degree, a little exercise might be impossible. If it were not for the fact that it takes so much heat to raise the temperature of the body a little, on account of the presence of water as its principal constituent, if it took only that amount of heat which is necessary upon the average

to raise the temperature of most substances one degree, running a mile might be quite sufficient to produce a coagulation of all the albuminous material in the body, and therefore death.

That is to say, the regulation of the temperature of the human body rests first of all upon this fact: that you have to heat water so much in order to raise its temperature a little, and then, in the second place, upon the effect of evaporation. The effect of evaporation is to cool the body very much, because you have to put a lot of heat into water in order to evaporate it, and since evaporation is the only way of cooling the body when the temperature of the environment rises to the temperature of the body this is a matter of the first importance, as everybody knows from his own experience in hot summer weather. It is a priceless advantage in the economy of your body that so much heat is taken up in the evaporation of water during sweating.

One of the factors that greatly influence the circulation of water on the earth is the way in which it clings in the soil. Indeed water clings better, on the whole, than any other substance. This is due to the phenomenon which everybody has heard of as capillarity, and which is well illustrated by the action of a sponge in soaking up water. If you study this process you will find that it is easy to represent the sticking power of a liquid in the soil or in any finely divided matter by the height to which it can rise in a small capillary tube, in a very fine tube. Water rises to a very great height relatively to other substances in such a tube, and for the same reason it sticks very tight in the soil and water rises to a great height in the soil. That is one reason why great portions of the earth are habitable, or at least can grow crops. If water did not stick as well as it does, a large portion of the fertile earth would be sterile.

But here again we have come upon a property of water which is just as important in the body as it is in the meteorological cycle. The living cell may be compared to a microscopic swamp, to a swamp of inconceivably fine dimensions. There is water running through it, and it consists of a very intricate meshwork of only partly known nature. In this swamp—this microscopic swamp, if I may call it that—these same forces, these same capillary forces, are of decisive importance. And here again it is the particularly great capillary activity of water that is one of the factors that determine the nature of physiological processes.

There is one more point that I want to refer to about the inorganic, the meteorological cycle, because it is a particularly interesting and important one, although this one seems to have no highly important direct bearing upon our own bodies and our own

life process. What causes rainfall? It takes a good many things to produce a precipitation of rain, but we may begin at the beginning and say that at least you can not have rain falling out of the air unless the air has become supersaturated with water vapor. The way to bring about that condition is to cool air that is pretty moist, because the amount of water vapor that the air can hold varies with the temperature. For instance, if you go down to the freezing point, to 32 degrees Fahrenheit, the amount of water vapor when the air is quite saturated is almost exactly one half of the amount of water vapor that is in the air at about 50 degrees Fahrenheit. Suppose, then, you have air that is three quarters saturated at 50 degrees Fahrenheit. Cool it down to 32 degrees Fahrenheit and it becomes not three quarters but three halves saturated; that it to say, it has 50 per cent. more water than it can hold. That water will come out in the form of rain.

This difference, a difference of 100 per cent. in the amount of water vapor that the air can hold, is far greater than the difference in the amount of the vapor of any other substance that the air can hold. That is to say, if you had any other substance at 50 degrees Fahrenheit, any other substance whatever, and the air were just three quarters saturated with it, and you cooled it down just to 32 degrees Fahrenheit, then you would not have reached the saturation point and the vapor would not fall out.

If there were not this property, rain would be a comparatively rare occurrence. Moreover, unless rain falls, unless water comes out of the air, there can not be further evaporation, because you can only evaporate into air which is more or less empty, so far as the water is concerned; that is to say, the whole meteorological cycle, the circulation of water, depends upon the rate of precipitation quite as much as upon the rate of evaporation, and the rate of precipitation of water is great because of this property of water.

I think I have perhaps said enough to make clear to you something of the natural importance of water. Such are the reasons why it is possible to say that what is happening on the earth in the last analysis is a circulation of water and the results of that circulation. This is true not merely because there is a great deal of water on the earth, but also because water is a remarkable substance that has a good many unique peculiarities. But in discussing these properties, I have thus far spoken only about what may be called the physical peculiarities of water. Water is quite as important a substance chemically, and indeed I think we may say that the most important clues that we find in the properties of water to our understanding of what is happening in our every day life are to be found in the chemical properties of water rather

than in its physical properties. This leads us back to the great French chemist Lavoisier, the most eminent victim of the French Revolution and the man who perhaps made the greatest contribution to science of the eighteenth century.

Lavoisier, studying the process of burning, of combustion, of oxidation as we call it, discovered that when things burn they combine with oxygen. Those of you who are not chemists and who have not studied chemistry will of course always feel a certain discomfort when one talks about the union of atoms. Atoms can not be seen. They are hard to imagine. But somehow or other the burning of tin for instance or the burning of mercury, is the combination of one or more atoms of the one element with one or more atoms of the other element. Tin and oxygen combine to form the oxide of tin. The atoms somehow or other fasten themselves together. That is what Lavoisier found out. He did not express it in terms of atoms, but he saw that these elements combined. So it is in the case of the burning of hydrogen, and water is a compound of hydrogen with oxygen. Atoms of hydrogen, two in number, combine with one atom of oxygen to form H_2O, according to our present way of stating the case.

Well, having discovered the nature of combustion, Lavoisier turned to all kinds of cases where there was combustion. He proved, for instance, with Laplace, the great astronomer, in one of the most remarkable collaborations in the history of science, that in the last analysis our life activity, so far as it is chemical, is oxidation. The oxygen that we breathe into our lungs is combined with the various elements that make up our foods, and then the products are turned out as carbonic acid gas, which is nothing but the oxide of carbon, the result of burning carbon, and water.

Then, reflecting further upon this, reflecting not only upon the chemistry of the process but also vaguely upon the energy that was involved, so far as it could be represented by the heat of the process, Lavoisier saw the real nature of the process, Lavoisier saw the real nature of the organic cycle and stated it clearly. He perceived that plants draw from the air that surrounds them and from the mineral kingdom the necessary materials of their organization; animals take from the plants that which the plant has formed, directly in the case of the herbivorous animals, indirectly in the case of the carnivorous animals, and build it up into their bodies, and finally the processes of combustion, fermentation, and putrefaction are continuously returning to the inorganic world the materials that were taken up originally by the plant. Of course

these materials are not merely water, nor merely water and carbon dioxide, but also other substances.

But note this. In the organic cycle water and carbon dioxide are free; the other things are fixed. Those things that are free in the physical sense are also free in the economic sense, under a wide variety of circumstances. You don't have to pay, at least in New England and in many parts of the world, for the water and carbon dioxide which are the principal foods of the plant; all that you have to pay for are the so-called fertilizers, which make up an infinitesimal fraction of the material taken up by the plant. Indeed, if it were not for the mobility of water and carbon dioxide in this cycle that Lavoisier first understood, there would be no vegetation on the mountain tops. How could the material get there? The mountain tops would necessarily be bare. Not only the mountain tops, but everything would be bare except the waters of the earth. It is because water and carbon dioxide circulate, circulate rapidly and penetrate everywhere and stick when they get there, that there is a widespread vegetation, that there is an intense organic activity on the earth.

But now what of this process that goes on in the plant? Lavoisier could not understand it. It goes on in the green leaf, and the green leaf is truly the symbol of life. It is the starting point of life. It is the factory in which are created the materials of your body and mine, of the body of every living thing. These materials are created by the conversion of water and carbonic acid gas into sugar and oxygen through the influence of solar energy and with the fixation of that energy. Sunshine, water and carbon dioxide, if one may speak very loosely, are the components in the green leaf from which sugar or starch and oxygen are produced. The oxygen is turned out—the oxygen, please note, that had combined previously in your body with hydrogen and carbon in the burning that is the essential process of your own activity. In the leaf this process is reversed. The energy of the sun is fixed in the leaf, and that is the source of the driving force of your body and of the driving force of every animal body.

And not only that, it is the source of our fuels generally. If you will reflect for a moment, and remember that not only wood, but coal and petroleum, gasoline, what you will that is combustible upon this earth, is stored solar energy that has been fixed in the green leaf in the past, you will realize the extraordinary economic importance of this process. You will then realize that the cycle is, in fact, not only from the standpoint of the material changes, but also from the standpoint of energy, of horse power, of what you

must buy and pay for as a source of any sort of material activity, the decisive factor on the earth.

Since we can increase this process of photosynthesis, since there are still portions of the earth that are not adequately utilized, it is conceivable that one of the solutions of the problem of the increasing demand for energy may be to grow more available energy, for example, in the Amazon basin, where there are forests that it does not pay to cut at the present time. We might, for instance, turn a vast amount of solar energy that is not being utilized at the present time, or that is being expended in a manner that we can not ourselves turn to account into starch and sugar, into industrial alcohol, and so get a substitute for gasoline. That is an idea that has been in the minds of chemists, of course, for many years. One does not know how economic conditions will develop. At all events, we have here the clue to an understanding of the sources of energy on the earth. Aside from the fixation of energy in the organic cycle, and aside from the water power and other sources of energy in the inorganic cycle, there is little enough of any kind of energy that is available.

You might perhaps have expected me to say something about water in medicine, since this is a medical school lecture. Water is indeed important in medicine, but not, I suspect, in a manner that makes it possible for a lecturer to explain in two words its importance. There are diseases involving water. Of course dropsy involves the physiology of water in a remarkable degree. And there are processes that might be regarded as in a certan sense the opposite of dropsy, such as the curious dehydration of sick babies. In many cases they lose water, and it is difficult, or impossible, to get it back again. I can only say that perhaps because these are in some respects simple phenomena—I say in some respects—we know just enough about them to know that they are so complicated that it is really difficult to explain them or even to understand them at all.

And so I shall, I fear, have to omit the more practical and immediate bearings of the physics and chemistry of water upon the organism, especially under pathological conditions. It is the principal constituent of our bodies, it is the principal substance that enters our bodies, it is the principal substance that leaves our bodies, and it is, as I have said, that substance whose movement in the inorganic world and in the organic world constitutes the first, the most fundamentally important, activity in the world that we live in.

INTELLIGENCE TESTS OF CERTAIN IMMIGRANT GROUPS

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THE influx of the foreigner into this country only became a serious problem with the shifting of the Old World source of the immigration from North to South Europe. The early situation in our national history was relatively simple. We had up to the Revolution, and forty years beyond, what constituted a genuine colonization. In fact, it was only after 1820 that a definite count was made of immigration. Even from this date until the Civil War, though the arrival of new-comers from Europe was constantly accelerated, the type of migration made for colonization of our free land and permanent citizenship.[1] In the two decades following the outbreak of the Civil War, the curve of yearly increase of immigration began to rise very rapidly, yet the source of the stream still remained Northern and Western Europe and the British Isles. The destination of this immigration, however, began to be more and more the rising industrial centers of our country and decreasingly so the rural districts—although it appears that the peasantry of Scandinavia and Germany often continued into the free lands of the Far West, the industrial workers of Great Britain, Germany and the bulk of the Irish went into the urban centers more particularly. Wherever this immigration went, it nevertheless fitted fairly readily into our socio-economic folkways and mores, and the biological amalgamation of the "Older Immigration," as it has been called, was in line with the racial stocks[2] already in the country.

[1] The existence of free land in America has had considerable influence upon our theories of government, our attitudes toward property, freedom and the socio-economic order generally. The significance of free land for racial amalgamation and cultural assimilation has been no less important, but less often noted.

[2] Race is used in this article in the popular rather than in the strict anthropological sense. Properly speaking there are no "races" in Europe, but only "sub-races." *Cf.* Retzius, "The So-Called North European Race of Mankind." *Jr. Roy. Anthrop. Institute*, 39: 277-313. *Cf.* also introductory chapter in Reuter, E. B., *The Mulatto* (1918) on use of term "race."

With the ever-increasing concentration of industrial controls and the accompanying specialization, and withal simplification of production processes due to the introduction of machine methods, the demand for cheaper, semi-skilled and unskilled labor became imperative. The rise of Germany to industrial power, the reaching of a point of stable population growth in Great Britain and the Scandinavian countries eliminated them as sources of this cheap labor. In consequence, we have a noteworthy change to the South and Southeast of Europe, and even to Western Asia, for this supply. In the short span of twenty years the shift in the center of gravity of the immigration to this country became the "common talk" of economics, sociology, political science and demography. The following table illustrates the now familiar facts:

TABLE I[3]

SHOWING THE SHIFT IN THE SOURCE OF IMMIGRATION TO THE UNITED STATES

(In terms of percentages of total from various sources)

Country	Year	Per cent.	Year	Per cent.	Year	Per cent.
Great Britain	1882	22.8	1907	8.8	1914	6.0
Germany	1882	31.7	1907	2.9	1914	3.0
Scandinavia	1882	13.8	1907	3.9	1914	2.0
Total Western European Countries	1882	71.3	1907	17.7	1914	......
Italy	1882	4.1	1907	22.2	1914	26.5
Austro-Hungary	1882	3.7	1907	26.3	1914	25.6
Russian Empire	1882	2.7	1907	20.1	1914	23.0
Total Southeast and Eastern Europe	1882	18.2	1907	75.5	1914	75.6

The complete significance of this change in the source of our immigration we do not yet know. If the theory of General F. A. Walker be true, we may doubt whether immigration has been as important or necessary for the growth of the country, since 1850 anyway, as some persons imagine. Had we had no immigration from the middle of the last century on, according to Walker, our present population would be as large as it is to-day, but racially we should be a much more homogeneous people, or, at least, in the way of becoming so.

Now the meaning of the coming of the "New Immigration," as that from Southern Europe has been called, in the matter of racial mixture is an unknown quantity. The writer believes, however, that there is accumulating evidence from studies in general

[3] Table compiled from Ellwood, C. A., *Modern Social Problems* (1913) and reports of immigration. The term "Russian Empire" in the table included Russian Poland and other sections now cut away from the former empire. Racially most of the contribution from Russia was Hebraic or Polish rather than strictly Russian.

intelligence of certain immigrant groups, at least, which material, coupled with the results of researches in the inheritance of mental traits, should cause us to consider rather carefully the bearing which these facts may have on features of the racial mixture that will surely come out of the shift in the source and nature of immigration.[4]

The present paper will deal specifically with certain samples of the South European immigration in terms of general intelligence. The special question is: Leaving aside physical characteristics, differences in emotional traits and cultural contacts, what are the significant findings of psychology concerning the general intelligence of certain of these immigrant groups that have come to us so overwhelmingly in the past thirty years?

The nature of general intelligence need not detain us here. The uninformed should refer to the long series of important studies upon this question initiated by Binet in France, and expanded by Stern and his pupils in Germany, and particularly by Goddard, Terman, Thorndike and Yerkes in the United States, and more recently still taken up by a group of English psychologists—Webb, Burt, Hart and others. There are obviously several problems as to the exact nature of so-called general intelligence, its growth, its importance in successful life career, and especially as to its innateness (that is *in potentia*). On the latter point, the evidence at hand seems sufficiently valid to establish that general as well as specific abilities are transmitted by heredity. The precise biological nature of the units involved we do not yet know. Special talents may actually turn out to be due to the presence of separate units in the germ plasm, and all-around ability may be due to a conflux of several factors—multiple and difficult to segregate in the chromosomes. Whether in fact, general intelligence is shown to be simply a convergence of special traits in certain patterns, as Thorndike might assume, or whether due to a more general factor as Spearman seems to hold is unimportant for our present paper. Though the entire data on the mechanism of inheritance are not at hand, and even admitting that the subtle influences of environment have not always been completely segregated and controlled in the studies made, the writer believes that our social programs for education, Americanization, amalgamation of the foreigner racially, can not nonchalantly ignore these important implications.

[4] Studies of the second and third generation of certain immigrant stocks are beginning to accumulate, but so far we lack psychological measures of the mental capacity of these various generations,—more especially of the strains that have gone into the mixtures. The writer, however, is in much sympathy with such studies as Drachsler's and others.

The studies of Galton, Woods, Pearson, Davenport, Thorndike, Earle, Starch, and others revealing the inheritance of intellectual traits appear reliable enough, irrespective of the peculiar biological form which subsequent research may reveal, to make the present status of the mentality of immigrant groups, if known, rather prognostic, to say the least, of what the mentality of the future generations of these peoples will be. In other words, the evidence appears rather conclusive for the inheritance of mental abilities, and if general intelligence tests reveal a given level of intelligence in an immigrant group may we not assume that we can predict something of the mental endowment which such a group will add to the future mixtures with other racial groups?

It is well recognized by all persons interested in racial mentality and has been recently reiterated by Major Leonard Darwin[5] that what we want is a high average intelligence in the masses, not a small group of selected superior intelligences, with the bulk of the population of low or inferior intelligence. Out of the constantly changing matrix of a high average intelligence will arise the superior-minded persons who will be able to make the outstanding cultural contributions of the future, while the good average mentality of the masses makes for solid citizenship, appreciation of high cultural values and successful group spirit. Any mixture which will lower the level of intelligence of a group and restrict the variability of the same will be deleterious. For instance, if the average intelligence of certain of the South European stocks which have come to us in the past twenty-five years should prove to be as high as that of the older American stock (i. e., of North European ancestry) the problem of mixing the older and the newer stocks, so far as general intelligence is concerned, will not be serious. However, on the other hand, if the Latins, say, who come to us should prove to be but four fifths as intelligent on the average and less variable when compared with the North European offspring in this country, the racial mixture between the two may be damaging to the welfare of the country.

With the methods of testing general intelligence that have come out of psychological investigation and with the implication of heredity in mental endowment, let us review the significant studies which throw light on the matter of immigrant mentality. On the basis of these we may then be able to note certain important bearings of these findings on the problem of immigration as it relates to racial mixture and the general intelligence of our future population.

[5] Darwin, L., "The Field of Eugenic Reform." THE SCIENTIFIC MONTHLY, 13: 392.

The writer will review three or four studies made during the past five years which deal with racial stocks in various parts of this country and will then add notes on his own contribution which grew out of a rather extended investigation of certain South European groups in California.

In one chapter of the published data from the psychological testing of men in the army[6] is shown the relative standing in the mental tests of the foreign-born men of various nationalities found in that portion of the army which was tested. Each man tested in the army was given a final letter rating ranging from A to E depending upon his raw score in either the alpha, beta or individual test. The alpha, as is now well-known, was devised for literates of ten years mental age and above, the beta was devised primarily for men of low-grade mentality, but was also used for illiterates or for men who did not understand the English language well enough to handle alpha. The individual tests were exclusively used for low-grade mentalities who did not score well or at all in the group tests (alpha and beta.) The men of high mentality were given ratings of A and B. Men in these classes were considered, other things being equal, as being prospective officer material. Grades C and D made up men of the grades of privates, but those of D rating were discovered to be rather poor military "risks," to borrow a term from insurance practice.

The following nationality groups are selected as samples from a longer list showing the rank order of countries according to the percentage of men in each nationality group receiving their final letter ratings in D, D—, and E, and also in A and B.

TABLE II[7]

SHOWING THE PERCENTAGE OF MEN OF SAMPLE NATIONALITIES RECEIVING FINAL LETTER RATINGS UNDER THE GIVEN CLASSIFICATIONS

Nationality	Per cent. D, D— and E	Per cent. A and B
Total White Draft	24.1	12.1
All Foreign Countries	45.6	4.0
England	8.7	19.7
Germany	15.0	8.3
Sweden	19.4	4.3
Austria	37.5	3.4
Ireland	39.4	4.1
Russia	60.4	2.7
Italy	63.4	.8
Poland	69.9	.5

[6] *Memoirs of the National Academy of Sciences*, 15. *Psychological Examining in the United States Army*, Pt. III, pp. 693-700.

[7] *op. cit.* p. 696: The omitted nationality groups fall variously in the range of the percentages given in this table. The totals for the white draft and for the total foreign nationalities are given for comparison.

In general the superiority of the Nordic stocks over the others is evident in this table. No assertions of language handicap can be brought against these findings, for the men who were unable to manipulate the verbal test, alpha, were given the performance test, beta, or the individual performance tests. Over 85 per cent. of the Italian group, more than 80 per cent. of the Polish group and 75 per cent. of the Greeks received their final letter grades from the beta or other performance examinations. The corresponding percentages for the Northwestern Europeans were: for the English, about 8 per cent, for the Germans slightly over 30 per cent., for the Swedish about 58 per cent.

It is interesting to compare these figures with those compiled for the Southern and Northern negro draftees: 82.1 per cent. of the former received final letter ratings of D grade or lower; for the latter the like percentage was 47.2. It will be enlightening to recall these comparisons of the negro draft with the Italians and others when reference is made to Miss Murdoch's investigation.

Dickson[8] in his study of first grade school children in certain public schools in California, while his number of cases was small, found important differences in the intelligence quotients of the various groups when tabulated under racial stocks. A summary of his data follows:

TABLE III

SHOWING DIFFERENCES IN INTELLIGENCE QUOTIENTS IN FIRST GRADERS BY RACIAL STOCK

Race	No. of cases	Median I.Q.
Spanish	37	78
Portuguese	23	84
Italian (chiefly Southern Italy)	25	84
North-European born	14	105
American (North-European ancestry)	49	106

With the average intelligence as measured by careful Binet tests revealing such differences in children of the first grade (the children were practically all of the same chronological age) would not the educability, the future economic success, and the contributions to national culture and well-being be differentially in favor of those of higher intelligence? True, the overlapping in such groups is considerable. The figures do not mean that *all* the Spanish do but four fifths as well as the children of North European stock. Some of the Spanish children have intelligence quotients above the average of the latter groups, but, on the other hand, the lower quotients of the Spanish group fall below the quotient of the lowest American child. So, too, the Portuguese and Italian groups over-

[8] V. Dickson, Unpublished Ph.D. thesis (Stanford, 1919), Tables from notes of Dr. L. M. Terman. Dickson's study will soon be off the press.

lap the other groups greatly. It must never be ignored that in dealing with averages in intelligence tests, the matter of variability must also be taken into account.[9]

The objection might well be raised that the differences in these racial groups found by Dickson are due to accident of environment which would be eliminated later. Would not, for example, school contacts wipe out, in large part, these differences? Might not home influences, such as use of the foreign tongue by parents and children, affect the standing of the Latin children in these tests?

With a view to investigating these and allied questions, Miss Thomson[10] five years later undertook the re-testing with Binet tests of the same children whom Dickson examined. In a period five eighths the total length of time demanded by our elementary public school curriculum one would imagine that any grave handicaps of language or family background would be largely overcome. After correcting Dickson's tables on the basis of chance errors in chronological age in his group, and eliminating, of course, from her group the cases which could not be found for re-testing, she presents the following table:

TABLE IV

SHOWING THE CHANGE IN MEDIAN I. Q. IN FIVE YEARS FOR RACIAL GROUPS

Race	1916 median I. Q.	1920 median I. Q.
Total South European	88.0	85.5
Portuguese	88.3	74.0
Americans (from one school)	111.0	110.5
Americans (from second school)	102.3	95.0

In another table somewhat differently arranged showing the ancestry of the pupils she gives the following from her own data:

TABLE V

SHOWING THE MEDIAN I. Q. OF CERTAIN RACIAL GROUPS IN PUBLIC SCHOOLS

Race	Median I. Q.	Range of I. Q.
South European	81.0	51 to 117.5
North European born	97.5	79 to 114.0
American born (North European ancestry)	102.0	62 to 139.9

While the number of cases is small for wide conclusions, it is apparent that the American group not only has the highest median

[9] It is unfortunate that the P. E.'s of these distributions were not at hand.

[10] Thomson, Mildred, "Validity of Stanford-Binet Tests as a Basis of Prediction of School Success" (A.M. thesis—Stanford University, 1920—unpublished). It must be noted that Miss Thomson was unable to secure more than two-thirds of the same children as Dickson tested, but there is no reason for believing this reduction in the number of cases was due to anything other than chance. Speaking in terms of intelligence, there is as much likelihood of an American family moving away as a foreign one.

I. Q., but that it is the most variable in range of I. Q. Miss Thomson notes:

It seems that as a whole the tests are as accurate a judgment of the mental capacity of the low foreign element as of the American children . . .

As to the matter of the alleged language handicap of the children of foreign parentage she comments:

Had language difficulty caused the first low median, the central tendency to change would now be plus. (That is, the overcoming of the language handicap by additional years in school would raise the median I. Q.) . . . . It seems evident that although the tests involve the use and understanding of language, low scores result not from the failure to understand, but from the failure to comprehend.

Miss Murdoch[11] has studied four racial groups in certain public schools in New York City in order to discover any mental differences in these groups with special reference to light on the problem of Americanization. Her groups included Hebrew, Italian, "American" and negro boys in the upper grades. The children all understood English, the Italian group being especially hand-picked, that is to say, only the boys who in the opinion of the school authorities did not suffer from any language handicap were tested. Miss Murdoch believes this selection of Italians was in favor of the brighter boys in this nationality. The children were not selected by age, but by grade, ranging from the fifth to eighth, inclusive, which means that the age groups ten, eleven, twelve and thirteen were most frequently represented. This grade selection, however, eliminated from the comparison all the pupils ten, eleven, twelve and thirteen who were still in the lower grades. This means that the selection was likely in favor of the more intelligent pupils of these age groups. The groups came from two different sections of New York City, both described as rather "undesirable." The writer of this article says:

At least, between Jewish and Italian boys and between white and colored boys respectively, no allowance for difference in neighborhood environment need be made.

The test used was devised by Pressey along the lines of the army alpha. Close to 500 cases each of Jewish, American, and Italian boys and 225 negro boys were examined. The Hebrew and American children had practically the same averages in the tests. The Italians and negroes while running somewhat together, with the latter slightly better, were decidedly inferior to the other two groups as measured by these tests. Taking the twelve-year-olds

[11] Murdoch, K., "A Study of Race Differences in New York City." *School and Society*, 11 (1920): 147-50.

who were tested as a sample—in the Italian group 13.5 per cent. equal or exceed the 50th percentile or median of the Jewish boys; 24 per cent. of the negroes exceed the median of the Jewish; and 50 per cent. of the Americans likewise. For the three age-groups having the largest numbers in the total group studied, i. e., the eleven, twelve, and thirteen-year-olds—the average is 15.5 per cent. for the Italians, 30.5 per cent. for the negroes, 53.7 per cent. for the "Americans" equaling or exceeding the median for the Hebrews.[12]

Whether the children studied according to age in relation to test results, or by grade location the Italians maintained "their position at the foot of the four races." Language can not account for the low scores of the Italian, for, as already noted, those who were suffering from difficulties with the English language were excused from the tests. Miss Murdoch writes:

> The fact remains that Italians who were thought by their teachers, principal, and the neighborhood social workers to be laboring under no language handicap were found to be very inferior to the other three races.

However, since the test used by Miss Murdoch was based upon verbal concepts, in part at least, the accusation may still be made that the Italian home does not furnish the English tools to its children so well as the Hebrew, negro, or American. Let us look further to see what additional studies have shown.

In order to test the matter of alleged language handicap and to investigate the general question of mental differences in immigrant groups in this country, the writer of the present article undertook in the years 1919 and 1920 to apply psychological tests to the children of certain South European and Latin American immigrants—viz.: South Italians, Portuguese, and Spanish-Mexicans—and to compare the same with groups of children of Northern and Western European ancestry.[13] Over 90 per cent. of the Latin stock (as we may call the former for brevity) studied were born in this country and practically all of the children of the latter stocks, or Non-Latin as they have been called. The survey was made in several cities and towns of the west-central portion of the state of California.

Several measures of mental differences, direct and indirect, were made. Such outside criteria as the grade location, teachers'

[12] The number of negroes at these ages is too small to warrant any wide conclusion concerning the intelligence of negroes compared with Italians. The negroes were a much more highly selected group perhaps than the Italians, further, the Northern negro is on the average higher than the average intelligence of the entire race in this country.

[13] This study will be published soon in *The University of Oregon Publications* under the title: "Mental Differences in Certain Immigrant Groups."

estimates of intelligence and of the quality of schoolwork were made and compared with the results of the psychological tests themselves. Of the latter there were two batteries of so-called general intelligence tests: the first, the army alpha, is a verbal test based quite extensively upon language and dealing with concepts of verbal nature; the other, a slightly modified army beta, adapted to school children who understand at least a modicum of English necessary for instructions. Rather than selecting the school children from certain grades the writer selected all the twelve-year-old children in the schools which avoided the biased sampling that must have arisen had children in one or two grades only been selected. By this method, then, all the twelve-year-olds from the entire public school systems in the communities surveyed were studied irrespective of their grade location. Incidentally the manner in which these twelve-year-olds distributed themselves through the grades indicates once again the fact that chronological age is no criterion to the pedagogical age of a child, of whatever racial stock.

This is no place for a detailed report of the findings in this study, but the pertinent facts for the problem of immigrant mentality will be briefly given. It was found that the actual grade location of the children is the best single criterion of their intelligence aside from the mental tests themselves. The comparative standings of the Latin with the non-Latin groups shows that the modal grade for the latter is the low seventh, for the South Italians, the high fifth, for the Spanish-Mexicans, the high fourth, for the Portuguese, the fifth.[14] On the basis of the teachers' estimates of general intelligence on a seven-rank scale the Italians are on the average .8 of one class-rank below the "Americans," the Portuguese are over one class-rank below the latter, and the Spanish-Mexicans over one and one quarter class-ranks below.

Coming directly to the results of the tests themselves, the important fact for us is that of overlapping of intelligence in the groups. The following tables give first the absolute differences as measured by the tests, then the measurement of the overlapping:

TABLE VI

(A)

SHOWING THE DIFFERENCES IN AVERAGES AND IN VARIABILITY IN GROUPS

Race group	Median Alpha	P. E. dist.	Median Beta	P. E. dist.
"American"	59.21	18.48	68.88	7.03
Italian	24.92	13.90	54.75	10.90
Portuguese	22.00	15.65	52.03	9.88
Spanish-Mexican	23.67	12.82	52.96	10.76

[14] The Portuguese group was not segregatable into half grades.

(B) ALPHA RESULTS

SHOWING PERCENTAGES OF FOLLOWING RACIAL GROUPS EXCEEDING THE QUARTILES OF THE AMERICAN GROUP (Actual and theoretical)[15]

Race group	Per cent. exceed. American Q1 (Actual)	(Theor.)	Per cent. exceed. American Median (Actual)	(Theor.)	Per cent. exceed. American Q3 (Actual)	(Theor.)
Italian	24.50	22.66	7.00	4.95	1.00	.55
Portuguese	22.50	23.88	10.00	6.55	2.00	1.07
Spanish-Mexican	21.50...	17.36	6.80	2.81	.75	.20
(C) BETA RESULTS (as under B)						
Italian	33.40	31.21	18.00	16.11	8.25	6.94
Portuguese	29.00	25.46	13.75	11.51	4.15	4.09
Spanish-Mexican	30.40	27 76	15.50	13.79	6.40	5.59

From the average for the American twelve-year-olds it looks at once as though measured by the alpha the Latins are decidedly inferior to the Americans. The beta averages, while more nearly alike for the Latins and Americans, still show a marked superiority for the latter. It must be noted that the range of the beta units is just half that of the alpha, hence the differences in the actual figures in the table are not indicative of the real differences revealed. It is still true, however, that the Latins approach their competitors more closely in the beta than in the alpha tests. The latter is based, as we noted, upon verbal concepts, while the latter is a so-called performance test operated independently of language. Were it not for the differences shown in other measures of intelligence, as, for instance, grade location, teachers' estimates of intelligence, and school marks, it might be imagined that the differences brought out in beta are more truly significant of the differences in ability than alpha. I have shown elsewhere that this is not the case,[16] but space prevents a lengthy discussion of the matter here. The following points summarize these facts:

First, the beta tests proved too easy for the American twelve-year-olds who were above their years in intelligence. This means that the tests were not diagnostic enough for these children and that there was a piling up of high scores for these children at the upper end of the scale. This narrowing of the spread of their actual abilities is the reason for the lower P.E. of the Americans in beta as compared with the Latins. Had the tests been more suited to their real mental capacities, some of them would have scored higher and the average for their group would have risen, and their variability as a group would have been greater. For the Latins the tests proved well suited for their capacities.

[15] The figures tabulated under "theoretical" are the computed measures of overlapping when the reliability of the tests are known. *Cf.* Kelley, T. L., "The Measurement of Overlapping." *Jr. Educ. Psychol.*, 10: 458ff.

[16] Discussed in writer's study mentioned in footnote No. 13 above.

Second, checking the alpha by correlation against the outside criteria, such as, grade location, teachers' estimates of intelligence, and the school marks, it was found that the alpha, the verbal test, was more diagnostic of the mentality and hence educability of the Latins and the Americans both than was the beta. In addition these correlations go to indicate that the asserted language handicap under which the foreign children are supposed to labor does not exist, at least so extensively as imagined.[17] As Miss Thomson put it the failure in the tests and in school is not based so much on failure to understand as failure to comprehend.

The measures of overlapping (sections B and C of above table) reveal more significant facts of mental differences in these groups than the differences in average score. If these tests are at all true measures of differences, and there is certainly much evidence that they constitute the best measure of mentality science has yet produced, may we not assume that the extent of the overlapping among the groups clearly concerns an important problem before us, namely: the relation of these differences to future racial mixture which is subsequent to our enormous immigration? If there is anything preponderant in mental heredity it appears that this question must be answered.

Taking the South Italian group as a sample of the Latins and near Latins (as we may term the Spanish-Mexicans),—if they equalled the American group, 75 per cent. of them should exceed the first quartile or 25 per cent. of the latter. As a matter of fact in alpha less than 25 per cent. of them exceed the lowest 25 per cent. of the Americans. So, too, with the median or second quartile, but 7 per cent. of the South Italians exceed the lower 50 per cent. of the Americans, and but 1 per cent. exceed the upper 25 per cent. of the latter.

It may be that alpha is unjust to the Latins even though there is considerable evidence that it is on the whole quite adequate for diagnosis of mental differences. It may even be that the language difficulty which a proportion of the Latins certainly had when they entered the public school has persisted until its effects are

[17] It is rather interesting to recall that thirteen years ago Ayres in his book, *Laggards in Our Schools*, pointed out that language difficulty did not operate as a factor in school retardation. He wrote: "Wherever studies have been made of the progress of children through the grades, it has been found that ignorance of the English language does not constitute a serious handicap." (p. 116). Of course no one would argue that in children newly arrived in this country from foreign countries speaking another language would not be handicapped in the period of acquiring our tongue. But beyond that period, the trouble in retardation lies in other directions.

felt as late as five or six years after entry.[18] Therefore for those who would still maintain that alpha is too distinctly advantageous to American children, the overlapping in beta, in spite of the fact that the evidence is clear that this test is unfair to the American twelve-year-olds, still shows the latter superior. But 33 per cent. of the Italians exceed the lowest 25 per cent. of the Americans, but 18 per cent. exceed the lower 50 per cent. and but slightly over 8 per cent. the upper 25 per cent. There is no evidence that the beta was in any way unfair to the Latins either in content or presentation. All the children were tested by the writer personally in small groups and in each session members of all the racial stocks were present. The Portuguese and the Spanish-Mexicans compare less favorably with the Americans than the South Italians.

We may now conveniently summarize the results of the experimental findings on this subject before passing to interpretative paragraphs.

The army tests on recruits and draftees showed that the Latins and other Southern European (also certain Eastern European) groups were decidedly inferior to the men who were natives of Northern and Northwestern Europe. The Dickson-Thomson studies have presented good evidence that the intelligence of the racial groups, at least of those investigated, does not improve by education, and further that in the samples which they study the Latin groups are on the average eight tenths (.8) the average intelligence of the American children of North European ancestry. Murdoch's survey revealed that as measured by the Pressey scale of general intelligence, the Italian groups which she studied were decidedly inferior to the American and Hebrew children tested, and even slightly lower than the negro children measured at the same time. Her twelve-year-old group (which we noted was a selected sample) compares quite noticeably with the writer's. In her results she reports that 13.5 per cent. of the Italians equaled or exceeded the median of the Americans. The writer's figure for a similar measurement of overlapping was but 7 per cent., but the difference may be due partly to the nature of the test and partly to the fact that his sample was not at all handpicked. It may be due to actual differences in the intelligence of the group. The important point, however, is the likeness of the two studies.

[18] The writer in answering those who maintain that all differences in mentality (barring the extreme feeble-minded) are due to environment and opportunity, is always puzzled to know how these persons account for the distribution of children at 12 years of age, some in third, fourth, fifth, sixth and seventh grades, when they all started in school at the same time.

One may use norms which were developed[19] for translating the alpha scores of school children into Binet mental ages. If this is done it is found that the Latins measured are on the average two years retarded as compared with the American groups studied. Again the caution must be repeated that the range of scores in each group is wide, meaning that the differences are relative not absolute.

Space forbids further comment on the studies themselves, but we must turn before concluding to a few paragraphs on the probable bearing of these findings upon the problem of immigration and the mixture of immigrant stocks in this country.

If the researches into mental heredity have the validity which we suspect, then the differences shown in these investigations just cited are simply reflections of what is found in the general adult population. The findings of racial differences in immigrant stocks revealed in the army lend weight to this assumption. Further it is interesting that the preliminary testing of the Japanese and Chinese made in California indicates that these Oriental immigrant stocks compare very favorably with the American population of North European ancestry in the same neighborhoods. Surely the language handicap is of greater potency in the Oriental than in the European. So it seems that these methods of testing have enough pertinence to make us pause and consider the meaning of their findings.

As noted at the outset of this paper, we have shifted the source of our immigration from North to South and East Europe, and further we have drawn more and more upon a low type of peasantry as compared with the rather good average industrial and agricultural classes that formerly came to us from German, Scandinavian and Anglo-Saxon countries.

As we noted above[20] the problem of mixing racial stocks is one of producing high average intelligence in the masses so as to lay the biological chances for the production of each generation of the superior persons who will make the greatest advances for their generation. If the mentality of the South Europeans who are flooding this country is typified by the mentality of the three groups studied by the writer and others, the problem of future standard of living, high grade citizenship and cultural progress is serious. The writer does not attempt to say whether these findings are

[19] From norms developed by Drs. S. C. Kohs and W. M. Proctor at Stanford University (1918-19). *Cf.* Proctor, W. M., "Psychological Tests and Guidance of High School Pupils." *Jr. Educ. Research*, Monog. 1, No. 1, pp. 70 (1921).

[20] *supra*, p. 5.

typical of the entire racial groups from which these samples came. None of these studies is an investigation of the whole population of Portugal, South Italy, Spain or Mexico. They are surveys of these stocks as actually found in the usual immigrant settlements in this county. However, the writer stands firmly upon the ground that the evidence points to the fact that these samples are *very typical of the immigrants who reach this country* from these European sources. Is not this after all the *significant thing?* For instance 85 per cent. of the total immigration from Italy in the past 30 years has been from the same districts of South Italy from which the largest sample of the writer's own investigation and that of Mr. Dickson and Miss Thomson came. The indirect evidence is that Miss Murdoch's Italian subjects were also from South rather than North Italy. In fact it is not impossible that the Italian in California is even a little superior on the average to his confrère who has neither energy nor ambition to get out of the industrial centers where most of these people first settle in our country. Of the Portuguese the writer can only venture a guess that he is much like the Portuguese found elsewhere in the United States, principally in New England. The Spanish-Mexican groups appear typical of the immigrants of this stock.

Does not the evidence accumulating, one phase of which has been reviewed here, point conclusively to the fact that a continued deluge of this country of the weaker stocks of Europe will ultimately affect the average intelligence of the population of this country? It is comment everywhere that the better stocks are losing ground compared with the poorer in the matter of offspring. The more intelligent classes are practicing, in one way or another, a conscious control of the number of their children. The result of this must mean a shifting in the average intelligence of the population toward that of the poorer stocks. Now hybridization of stocks is already taking place. It does not seem to be true that the inferior stocks always mix with their own kind—the history of the Kallikaks and such like proves that these stocks are constantly sending out their tenacles into the higher biological strains. Have we not been caught in the myth of the Melting Pot and in a sort of pious wish that all was well and that nothing could happen to us? The general economic progress of the past fifty years may have made us myopic of the larger meaning of these accompanying changes in our population. As Irving Fisher put it:[21]

> Mechanical inventions . . . have given us more and more room for expansion and we have mistaken this progressive conquest of nature for a progressive improvement in ourselves.

[21] Fisher, I.: "Impending Problems of Eugenics." THE SCIENTIFIC MONTHLY, 18: 215.

Certain sentimentalists have talked glibly of *assimilation* of racial stocks. This presupposes the capacity of one stock completely to take over another and make as the original stock was. There may be cultural assimilation (even this is doubtful in a technical sense), but there can not be biological assimilation. What we have is amalgamation, and as Conklin and others have pointed out, amalgamation means a hybrid stock, a stock compounded out of the elements of the two or more strains running into the new generation.

It is true that biologically the mixing of the North and South European is hardly analogous to the mixing say of the white and the black races or the whites and the mongoloids. Biologically as previously noted[22] the European stocks are actually sub-races. Furthermore in reference at least to the latter stocks the problem is not an *all or none* principle. If these tests of general intelligence are at all significant it is evident at once that there is considerable overlapping in the various groups. For the future of this country a careful selection of the best in all the European stocks might be thought desirable. However, it is a common assumption of breeders and eugenists that for the production of a stable, homogeneous, strong stock isolation, group inbreeding and some occasional, but not too great, influx of exotic strains is necessary.[23] The incoming of even somewhat distinct racial stocks might be profitable if of a high average intelligence and wide variability.

What we want, then, in brief is such a selection of European peoples that they will add variety to our population but not lower its intelligence. We have, of course, the comparable problem of preventing the continuance of inferior lines in the present population in this country without adding any more congenital liabilities to our people.

In conclusion the writer wishes to submit a few comments upon the practical phases of immigration problems which he believes grow out of these partial but significant investigations of mentality in immigrant stocks.

(1.) There must be a change in public opinion as to the desirability of large numbers of immigrants. We acquired the habit previous to 1914 of pointing proudly each year to the rising influx of foreigners into our land. The economic exploitation of cheap, unintelligent labor from abroad has fastened a serious racial as well as social-economic problem upon us. It has resulted in considerable ethnic displacement. The "Older Immigration" has con-

[22] *Supra*, p. 2—ref. Retzius, etc.

[23] *Cf.* East and Jones, *Inbreeding and Outbreeding*, p. 264.

stantly lost ground in the face of the "New." The public opinion of this country needs arousing to opposition to the policy of economic stimulation of immigration to this country for the profits of the few at the expense of the general well-being.

(2.) This means that immigration should be controlled in the interests of the national welfare. The present law is inadequate, unjust and ill-administered. To base the percentages of admission on the number of immigrants of various nationalities in this country in 1910 is merely to continue relatively the same evils as heretofore. At present there seems to be some evidence that desirable people from Northern Europe and certain English colonies are being kept out while the ratio for Italians and Southern and Southeastern Europeans is large because of the "high" tides of immigration which they reached previously. Moreover, a literacy test is not an adequate criterion of the kind of persons we want. Due to inequality of educational opportunities in Europe, it is likely that persons of good intelligence may be barred because they can not read or write while persons really subnormal, but possessed of a modicum of education are able to pass the meagre demands on their reading and writing abilities at the gates of the country. Davenport has suggested a study of family strains in Europe, but this is expensive and impractical of execution.

The writer believes a set of well-worked out physical and psychological tests applied to all applicants for entrance into this country would assist in rejecting those whom we do not want. While the psychological tests are not perfect, they are far superior to any other scientific means which are available. The remarkable success of mental testing in our military organization during the war should dispel serious doubts as to the practical value of psychological tests for determining intelligence rankings and from that predicting success at tasks such as modern complex society demands. It would well repay our government to spend a considerable sum if necessary (say half the cost of one battleship) to devise under expert advice a set of tests to fit the needs of the immigration bureau. With adequate time at their disposal a body of experts could arrange a battery of tests, with norms, superior to anything yet at hand. Tests could be devised which would take into account the different linguistic and cultural backgrounds of the applicants, and further the non-verbal test offers possibility of expansion that is still unknown. On the basis of such tests, legal enactment could determine the standards to be set. In addition, if necessary, some differential standards on absolute numbers admissible any year could be laid down. It seems to me that there is not a better piece of service for the National Research Council than

an attack upon this problem with an effort to secure the national government's support and adoption.

True, there remains after such a program, if it is ever accepted, the entire matter, noted already, of the inferior strains in the population now present in our country. Were we to set out on a sensible program regarding the immigrant, we should be led ultimately into another analogous one concerning the inferior stocks already extant in our population. Linking up these two programs with a sane educational policy we might look forward to a true national greatness. For who doubts that the contributors to a high culture must be a high-minded race?

On the other hand, if we continue our present muddling, irrational, hit-and-miss method of dealing with these two related problems and the country becomes more and more inundated with inferior stocks, the questions of American citizenship, education and cultural progress will be increasingly difficult of solution. In fact, ultimately such problems as we now see them will be submerged in the low standards of life and culture which arise out of a lessened average intelligence in the general population.

The picture may be pessimistic. It should arouse us to action. To those who are pragmatists and meliorists the matter is not hopeless, except in so far as the individuals and communities involved fail to recognize the gravity of the matter and naïvely close their eyes to the realities. Blind leaders of the blind, we may well shake our heads in serious meditation. But if the public consciousness of the country, under good leadership, realizes the problem soon enough there is no reason why we should not successfully solve this issue and assure our country's place of leadership in the world.

CONCEPTUAL THINKING[1]

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By Dr. WALTER LIBBY

IN the recent newspaper controversy concerning evolution, one of Mr. Bryan's supporters displayed some impatience at the emphasis placed by scientists on resemblances. He protested in the name of logic against what seemed to him an undue insistence on resemblance, resemblance, resemblance! But unless we take account of the similarity among phenomena, how are we to arrange and classify the data of physics, chemistry, botany and zoology, or arrive at the concepts of which the propositions and syllogisms of the logician are composed? We can have no science of distinct existences ununited by the bond of likeness. It is only by virtue of resemblances that we are enabled to pass from the observation of particulars to the consideration of universals. Bain and other psychologists are so far from belittling the ability to discover the bond of similarity among phenomena, often apparently unlike, that they regard it as characteristic of the man of genius. For James, genius is the possession of similar association to an extreme degree. To the type of genius that *notices* the identity underlying cognate thoughts belong the men of science, and it is in the concept that the conscious identification takes place.

Conception, or the cognition of the universal aspects of phenomena, can be illustrated from the history of the biological sciences. For example, what Linnaeus called the "System of Nature" was in reality a system of concepts. His classification of plants, though it prepared the way for more natural classifications, was crude, because based on superficial similarities. He, as Harvey-Gibson says, "elaborated a complex and beautifully arranged and catalogued set of pigeon-holes and forced the facts that Nature presented to him into these pigeon-holes, whether they fitted the receptacles or not." His zoological concepts were likewise inadequate. Suffice it to recall his vague use of the terms *Insecta, Vermes* and *Chaos*. The likenesses revealed in animal structure by the comparative anatomists from Hunter to Cuvier and Owen led to a sharper definition of concepts and a more satisfactory classification. Paleontology afforded new materials for

[1] The second lecture in a series entitled "The Psychology and Logic of Research" given before the Industrial Fellows of the Mellon Institute, February 14 to May 2, 1922.

comparison. Lamarck introduced the term *Invertebrate.* Embryology and the use of the microscope led to fresh observations of likeness and to the establishment of the natural affinities of species and genera. Here might be mentioned particularly the discovery of the notochord—the key, as it has been called, of vertebrate anatomy—and the consequent use of the term *Chordata.* The coming of evolution made possible a phylogenetic classification of organisms and a subtler differentiation of biological concepts.

The dominance of conceptual thinking in the classificatory aspects of science is fairly obvious. For example, in adopting the terms *Quercus alba, Q. rubra* and *Q. salicifolia,* the seventeenth-century taxonomist merely associated a definite nomenclature with the distinct concepts of Virginian woodmen, who had observed the likeness of American and British oaks. In other aspects of science, where the importance of the concept is far less obvious, it is none the less real. In the study of human anatomy by means of dissection it is generalized or conceptual knowledge that one seeks and retains. Anomalous or exceptional structures—such as a triceps muscle in place of a biceps, or an over-developed *panniculus carnosus*—are either disregarded and forgotten, or remembered as anomalies and exceptions. In any case, what the student retains, after two years spent in the dissecting-room, is a generalized knowledge of the structure of the human body and not a memory of the particular cadavers that seemed to occupy the focus of his attention. The case is somewhat similar with your natural history museum. The biological collections consist wholly of dead symbols of living things. Bones are frequently represented by masses of limestone or silica. A single specimen may do duty for a species, genus or order. The mere external surface—the shape—may alone be preserved. Only one stage in an animal's development may be exhibited, or only one posture—the Megatherium pulling down a tree or a dinosaur in a more or less characteristic pose. Each specimen has value not as representing an individual but as symbolizing a group. Each concrete object, like a word in a catalogue, serves to recall a concept.

The importance of cultivating the habit of conceptual thinking has been definitely recognized since the time of Plato, and Plato's master, Socrates. The majority of people, according to the Platonic dialogues, are the slaves of their senses and never attain to a system of clear concepts. They fail to translate their perceptions into conceptions and to pass from the sensible world to the supersensible or intelligible world. Plato valued the sciences with which he was best acquainted—mathematics and astronomy—because they tend to wean the mind from what is sensory and transitory to what is conceptual and eternal. The concept triangle,

the triangle of definition, is more real than any of its visible representations. Discipline in conceptual thinking is perferable to utility. "You amuse me," he writes, "by your evident alarm lest the multitude should think that you insist upon useless studies. Yet, indeeed, it is no easy matter, but, on the contrary, a very difficult one, to believe that in the midst of these studies an organ of our minds is being purged from the blindness, and quickened from the deadness, occasioned by other pursuits—an organ whose preservation is of more importance than a thousand eyes; because only by it can truth be seen."

Plato's philosophy is interesting for us because modern science is just such a system of clear concepts as he had in mind, and it is a mistake to interpret his intelligible world as something invisible to-day but accessible to the senses at some future time. The scientist must turn away from the sensuous world of the artist and the child to the intelligible world of mathematics, physics and biology; from the eight or seven little boys seated on a fence to cube root and prime numbers; from the panorama of many-colored nature to the conceptual world of elements, atoms, ions and electrons. The sciences are a sort of shorthand way of conceiving phenomena. They do not give us nature in its richness and fullness. In the words of Mephistopheles, "Gray, dear friend, is all theory, and green the golden tree of life." Picturesqueness is sacrificed by the scientist for the sake of clearness and economy of thought. He casts his net now for one kind of fish, now for another. For an artist like Monet, water may be a shimmering variegated surface; for the child it may mean "to drink;" while for the chemist it may be H_2O, or, if he conceives it as an alcohol, H.OH.

Of course science has no monopoly of clear conceptions. In insisting on the value of an education in conceptual thinking, Plato had in mind the training of leaders in ethics and statesmanship, and thus anticipated by a few centuries the publicists and philosophers who to-day advocate, as a novelty, the application of the intellect in social and political reform or proclaim the cultivation of the scientific habit of mind as the sole means of maintaining and advancing contemporary civilization. He would have recognized Lincoln as a man of clear conceptions, gained through a unique self-education, by living in close contact with man and nature, by reading a few books with extraordinary care, by poring over the statutes of Indiana, studying grammar, arithmetic and surveying, conning the dictionary, passing in review the life of Washington and the history of the United States, following with a frontiersman's imagination the exploits of Robinson Crusoe, absorbing the wisdom of Aesop's Fables, weighing the moral principles of The Bible and The Pilgrim's Progress. Indeed,

clear conceptual thinking, the scientific habit of mind, was consciously cultivated by the moral philosophers of Greece, notably by Socrates, whose chief distinction is that he subjected to critical examination such concepts as virtue, temperance and justice. Speaking of this pioneer work, Stout says: "It is only at a late stage of mental development that an attempt is made to distinguish an identical or persistent element of meaning pervading the varying significations of a word. When the attempt is made, it constitutes an epoch in the history of thought. It is the beginning of definition and of the scientific concept."

Conception, or thinking the same in like circumstances, has its complement in discrimination. Association by similarity is offset by dissociation, integration by disintergration, synthesis by analysis, and the observation of congruity by the observation of incongruity. In this respect, there is a marked difference between one individual and another. Experiment shows that one student may recognize readily ten shades of gray where his classmate has the greatest difficulty in discerning any difference in shade whatever. Similarly, one mind is alive to shades of meaning that make no impression on another. Aristotle, the greatest of all scientific intellects, trained for twenty years in the school of Plato in conceptual thinking, the most acute among the Greeks, as he has been called, in noting differences and making distinctions, carried his investigations into almost all the realms of knowledge. His success was most marked in fields where his aptitude in the employment of general concepts was supported by a wealth of observational data. This is particularly remarkable in his researches in biology. In the *Historia Animalium,* for example, one discovers the trained thinker bringing order out of chaos by the application of the intellect to the facts of experience, so called. It is the custom among historians of a conservative type to belittle the medieval followers of Aristotle, and above all the scholastics. But even to scholasticism modern science is deeply indebted for the development of logic in general, and for the definition and differentiation of concepts in particular.

The use of language is the indispensable concomitant of clear conceptual thinking. We can not think of one of the lower animals advancing very far in logical thought. He is bound down for the most part to the fleeting images of things, and lacks the word (logos) by which they might be made permanent and independent of the continuum of experience. The intellectual development of the child proceeds as a rule *pari passu* with its command of appropriate terms. "Out of hundreds of English-speaking children," says Terman, "we have not found one testing significantly above age who had a significantly low vocabulary;

and, correspondingly, those who test much below age never have a high vocabulary. Occasionally, however, a subject tests somewhat higher or lower in vocabulary than the mental age would lead us to expect. This is often the case with dull children in cultured homes and with very intelligent children whose home environment has not stimulated language development. But even in these cases we are not seriously misled, for the dull child of fortunate home surroundings shows his dullness in the quality of his definitions, if not in their quantity; while the bright child of illiterate parents shows his intelligence in the aptness and accuracy of his definitions.'' Terman thus makes it clear that intelligence is not to be gauged by the extent of one's vocabulary, but by the exactness with which concepts are defined.

In the interests of the progress of both science and democracy, it is important that training in the precise use of words—especially the derivatives of those languages from which we draw our general concepts—should not lag behind other conditions of the development of the immature. As Walter Lippmann says, ''Education that shall make men masters of their vocabulary is one of the central interests of liberty.'' Franklin's success, both as a statesman and a scientist, was in no small measure owing to the severe drill in the use of the English language to which he subjected himself. Two other self-educated research men, namely, John Hunter and Michael Faraday, who, on first thoughts, might seem to bear witness against the view that language training is of importance in scientific investigation, prove on examination to furnish testimony in corroboration. John Hunter received little if any schooling. He turned in contempt from the opportunity of studying the classics at Oxford. Although, after reaching maturity, he was brought, through the closest association with his brother, William Hunter, in contact with scholarly traditions, he never overcame the defects of his early education. We are indebted to him for such concepts as ''arrested development'' and ''secondary sexual characters,'' but his pages are strewn with terms like ''the stimulus of death,'' ''the stimulus of imperfection,'' and ''sympathy,'' to which he assigned a significance now impossible to recover. The lack of language training, in spite of Hunter's genius and vivid personality, was detrimental to his influence as a lecturer and writer. Owing to this shortcoming, science has not yet reaped the full harvest of his tireless energy in research. For example, the recapitulation theory, as stated by him, seems to-day little more than a literary curiosity, though it may have influenced the progress of embryology through the interpretation of the younger Meckel. The case of Faraday was somewhat different from that of Hunter. Having received an elemen-

tary education, Faraday became apprenticed to a book-binder. For years he spent his leisure time in reading scientific works. At the age of twenty-one he gained the favor of Sir Humphry Davy by a lucid report of some lectures delivered by Davy at the Royal Institution. Faraday became Davy's assistant, traveled on the Continent with his patron, studied foreign languages, and made definite efforts to acquire the oratorical arts of Davy, a recognized master of scientific diction. Faraday's opportunities for language training, however, came just a little too late. He sometimes confessed his difficulty in formulating the ideas that occurred to him. He sought aid at the University of Cambridge and was indebted to Whewell for such terms as "electrolysis," "electrolyte," "ion," etc.

Language permits us to summarize nature, to express it schematically, to seize upon certain aspects of it—that is, to analyze phenomena with certain purposes in view. For Priestley the part of the atmosphere that supports life was "pure dephlogisticated air." Lavoisier substituted a new term and a new conception, viz., "oxygen." Davy spent a great deal of time proving that Lavoisier had a false conception of the element discovered by Priestley. We retain the name after having modified the concept. This we do with the greater freedom, seeing that the classical term "oxygen" is not self-explanatory, as is the analogous term "Sauerstoff." Gases were known in the last quarter of the eighteenth century as "kinds of air," or "factitious airs." As late as 1766, Cavendish called hydrogen "inflammable air." In 1783 and 1785, he made experiments that justify the conceptions expressed by the terms "hydrogen" and "nitrogen." It was almost impossible to think clearly concerning earth, air, fire, and water, the so-called elements, without having the terms "oxygen," "nitrogen," "hydrogen," etc., as symbols of the concepts corresponding.

Counting, measuring, weighing—the application of mathematics—must be regarded as among the best means of sharpening up our conceptual thinking. One classical example is Lavoisier's use of the balance in establishing the nature of combustion and giving phlogiston the quietus. "About a week ago," he wrote on November 1, 1772, "I discovered that sulphur in burning, so far from losing weight, rather gains it; that is to say, that from a pound of sulphur more than a pound of vitriolic acid may be obtained, allowance being made for the moisture of the air. It is the same in the case of phosphorus. The gain in weight comes from the prodigious quantity of air which is fixed during the combustion and combines with the vapors. This discovery, which I have confirmed by experiments that seem to be decisive, has made me believe that what is observed in the combustion of sulphur and

phosphorus may equally well take place in the case of all those bodies which gain weight on combustion or calcination. I am persuaded that the gain in weight of the metallic calces is owing to the same cause." Lavoisier followed up this work by the calcination of tin in 1774, and in the same year—after Priestley's discovery of "pure dephlogisticated air"—by the oxidation of mercury. In 1777, Lavoisier stated: that in all cases of combustion heat and light are evolved; that bodies burn only in oxygen (or *air éminement pur,* as he at that time called it); that oxygen is used up by the combustion, and the gain in weight of the substance burned is equal to the loss of weight sustained by the air.

The differentiation of terms and concepts is so necessary an accompaniment of the advance of science that no collection of examples can be regarded as adequate or as even fairly representative. Though Lavoisier in 1777 succeeded in giving to the concept "combustion" a much more clearly defined meaning than had attached to the "fire" of the ancient philosophers or the "flame" of Francis Bacon, in 1789 he still included "caloric" and "light" in his table of elements. In spite of the definition by Robert Boyle of the concept "element," and the attempt of Newton to determine the meaning of "atom," these ideas, inherited from the remote past, were at the close of the eighteenth century about to enter on a new series of transformations. In the seventeenth century Boyle's contemporary, John Ray, ascribed to the term "species" a definite, if not a final, significance, and Sydenham, seeking to establish by clinical observation distinct species of disease, succeeded in differentiating measles from smallpox, in defining chorea, in modifying the significance of the term "hysteria," etc. Progress in science may involve lessening or increasing the extension of a familiar term, determining anew the distinction between familiar terms, and introducing new clearly defined terms. Pasteur's studies in molecular asymmetry involved a reconsideration of the terms "tartrate" and "racemate" and a delimitation of the concepts which each of these terms expressed. An advantage is gained by substituting the unfamiliar "neurasthenia" for the familiar "nervousness," partly because the new term is unambiguous and partly because it is devoid of every popular connotation. In fact, our scientific terminology has become so much a thing apart that one may overlook the relationship between a common term like "weight" and a more technical term like "mass."

The researches of Schleiden and Schwann, which led up to the statement of the cell theory, were affected and, to some extent, vitiated by traditional conceptions concerning "cellular tissue" and the "cell." Robert Hooke was the first to use the term "cell"

in describing organic structure. He had examined charcoal, cork, and other vegetable tissues under the microscope and described them in 1665 as "all perforated and porous, much like a honeycomb." He could discover no passages between the minute cavities or cells, though he took it for granted that the nutritive juices to be seen in the cells of green vegetables had some means of egress. Hooke's observations were verified by his contemporaries. Grew, in describing the microscopic structure of plants, mentioned the infinite mass of "little cells or bladders" of which certain parts are composed, and Malpighi described the cuticle of the plant stem as consisting of "utricles" arranged horizontally. Caspar Wolff in his doctor's thesis (*Theoria Generationis,* 1759) reported the observation of cells and "little bubbles" which developed in the homogeneous layers of the embryo. In the works of Bichat, the founder of histology, the term "cellular tissue" was used, as indeed it is to-day, to indicate a certain kind of connective tissue. Treviranus and Link described the cells in vegetable tissues in 1804, the latter maintaining that they are closed vesicles incapable of communicating with each other. Professor John H. Gerould has recently pointed out, in the pages of *The Scientific Monthly,* the important part taken by Lamarck, Mirbel (the disciple of Caspar Wolff), and others in the development of the conception of the "cell" and of "cellular tissue." After the appearance of Moldenhawer's *Contributions to the Anatomy of Plants* (1812), which demonstrated that the cavities of vegetable cells are separated from each other by two walls, the attention of observers was diverted from the cell contents to the cell wall. The consequent misconception of the nature of the cell was in part corrected by Robert Brown's discovery of the cell nucleus and by the later discovery of protoplasm. It was before the full significance of the cell contents was realized that the cell theory was conceived by Schleiden and Schwann.

It is evident that advances in scientific thinking imply the use of clear concepts and clear terms. The term "neuron," employed by the early Greeks in the sense of "thong" or "sinew," was applied by the anatomists of the fourth century B. C. to the tendon as well as to the nerve. A considerable treatise alone would suffice to trace its subsequent meanings and those of its derivatives and at the same time to give an account of the investigations that from the time of Herophilus and Erasistratus have contributed to the elucidation of the concepts in question. The terms that represent to-day the so-called chemical elements have no doubt undergone a similar series of transformations in meaning. Distillation, crystallization, and other refining processes had to be brought into play before the concept—the spirit, the essence, the thing in itself—could be realized.

"WHO'S WHO" AMONG AMERICAN WOMEN

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CATTELL has made some stimulating statistical studies of the more eminent scientific men, including the distribution of their birthplaces and of their present residence.[1] Some years ago a study of the distribution of the first ten thousand persons in "Who's Who in America" appeared in this journal.[2] The conclusions drawn from these studies, while not to be seriously doubted, are so interesting that it appears worth while to test them by a similar study of a different group of notable people—the 1,687 women included in the last edition of "Who's Who in America" (Vol. XI, 1920-21), especially the 1,582 women concerning whom biographical data are given.

The distribution of the place of birth of 1,551 women who gave this information is indicated by districts in Table 1, as is also the ratio between eminent women and the general population of 1880.

TABLE 1
BIRTHPLACES OF WOMEN IN "WHO'S WHO IN AMERICA"

District	Number	Per cent.	Number per 100,000 at 1880 census
New England	333	21.5	8.3
Middle Atlantic	511	33.0	4.3
East North Central	347	22.4	3.1
West North Central	99	6.2	0.5
Southern	101	6.5	1.6
Mountain and Pacific	49	3.2	2.8
Foreign countries	112	7.2	....

This table reveals the prominent share New England has had in the production of eminent women, and the small share which the southern and western halves of the nation have had. "Who's

[1] J. McKeen Cattell: "Families of American Men of Science." *The Popular Science Monthly*, May, 1915, and THE SCIENTIFIC MONTHLY, October, 1917 (reprinted in "American Men of Science," third edition, 1921). An earlier study based on the starred scientists in the first edition is reprinted in the second edition of "American Men of Science," 1910.

[2] Scott Nearing: "The Geographical Distribution of American Genius," *The Popular Science Monthly*, Vol. 85, pp. 189-199, 1914.

Who in America" is published in Chicago and is edited by an Ohioan.

Of scarcely less interest than the variation among the districts is the variation among the individual states in the number of famous women they have produced. Table two shows for each of the leading six states the number and proportion of eminent women.

TABLE 2

SIX LEADING STATES IN THE PRODUCTION OF EMINENT WOMEN

State	Native	Per cent. of total eminent women	Ratio per 100,000 of general population in 1880	Number now residing in the state
New York	291	19.0	5.8	550
Massachusetts	171	11.2	9.5	237
Ohio	117	7.6	3.7	46
Pennsylvania	113	7.4	2.7	90
Illinois	90	5.8	3.0	107
Indiana	43	2.8	2.1	20
Minnesota	43	2.8	6.6	24

Table three gives the number of eminent women born in each state and the number now living there.

TABLE 3

BIRTHPLACE AND RESIDENCE OF EMINENT WOMEN BY STATES

State	Native	Resident
Alabama	19	10
Arizona	0	1
Arkansas	5	2
California	28	78
Colorado	0	14
Connecticut	54	62
Delaware	5	1
Florida	3	6
Georgia	9	13
Idaho	1	1
Illinois	90	107
Indiana	43	20
Iowa	24	11
Kansas	15	9
Kentucky	32	22
Louisiana	14	2
Maine	43	21
Maryland	28	30
Massachusetts	171	237
Michigan	33	17
Minnesota	18	24
Mississippi	10	2
Missouri	36	25
Montana	3	2
Nebraska	5	3

Nevada	2	2
New Hampshire	27	14
New Jersey	33	58
New Mexico	1	2
New York	291	550
North Carolina	7	11
North Dakota	2	2
Ohio	117	46
Oklahoma	1	1
Oregon	4	7
Pennsylvania	113	90
Rhode Island	16	11
South Carolina	4	3
South Dakota	1	0
Tennessee	20	10
Texas	6	5
Utah	3	3
Vermont	22	3
Virginia	35	16
Washington	7	12
West Virginia	6	5
Wisconsin	32	15
Wyoming	0	3
Countries outside U. S.	112	48
Not given	136	
Total	1,687	1,687

This table indicates that Colorado, Wyoming and Arizona, having a population of 260,000 in 1880, produced no women who have been included in this issue of "Who's Who in America." Furthermore, Idaho, South Dakota, New Mexico and Oklahoma, having a total population of 451,000 in 1880, have each produced only one. Thus these seven states with a population in 1880 of 712,000 are represented in "Who's Who" by only four women. On the other hand, New England, which had a scarcely larger population in 1880, contributed 333 eminent women. Similarly, the Southern States, with an 1880 population somewhat greater than that of New England and the Middle Atlantic States combined, produced only 99 famous women in contrast with 844 from these northern states. Not only were few eminent women born in the South about 1880, but still fewer now reside there, 63 vs. 99. The North Atlantic and New England States have attracted many notable women with the result that 1,148 of the 1,687 women listed now live there. In other words, these states produced 54.5 per cent. of the eminent women, but now have 68 per cent. of the nation's total.

This great centralization of production of famous women and of their present distribution may be due to the following in-

fluences: The presence of more educational institutions in the northeast, and the greater emphasis placed on education there.

Unquestionably there are sectional differences in ideals. In parts of the South, for example, an intellectually ambitious woman is not in favor.

The fact that men outnumber women in the West tends to encourage early marriage in the West. Relatively sparse population and more recent occupation also tend to cause life to be on a somewhat more primitive plane, with less opportunity or incentive for the type of achievement recognized by inclusion in "Who's Who." Western women who do not marry early are more likely than eastern women to have opportunity to become school teachers, clerks or business women.

Selective emigation certainly helps explain the distribution of the birthplaces of the eminent. As a rule, the highly intellectual type do not become frontiersmen. Pioneering calls for physical vigor and daring rather than high education or unusual intelligence. Furthermore, the highly intelligent type generally are in fair circumstances, and it usually is the poor who emigrate, not the well-to-do. Hence, for a number of reasons, there is a tendency for the intellectual type of people not to emigrate, unless it be as missionaries, but to remain where they can make the most use of their ability and education. Thus many have remained in the older states, or have moved into the older communities in the Middle West, rather than going to the Newer West. Consequently, few infants possessing unusual intellectual endowment are born on the frontier or in the Newer West.

The presence of nearly ten million negroes in the South reduces the South's contribution of eminent women in proportion to its total population, for no negress is included in this volume of "Who's Who."

The climate of the North is more favorable for mental activity than is the often rather enervating climate of the South. It likewise favors physical vigor and thus increases accomplishment. Climate also doubtless has played a part in reducing the production of eminent women in parts of the West. While the climate of the arid and semi-arid west may possibly favor intellectual activity and physical vigor, it can not be disputed that the frequent droughts, unseasonable frosts, etc., have tended powerfully to encourage the emigrating of the exceptionally alert and resourceful people. Such people tend to go into regions where the opportunities are less uncertain.

In addition to place of birth and residence, note was taken of occupation, education and state of marriage. It was found that

53 per cent. of the last 950 women in "Who's Who" are married. Many occupations are followed. Eighteen chief types were listed. The most important eight, with the number engaged in each, and the per cent. of the total are shown in Table 4.

TABLE 4

OCCUPATIONS OF WOMEN IN "WHO'S WHO IN AMERICA"

Occupations	Number of women	Per cent. of women
Writers	714	45 3
Education	244	15 6
Social workers	127	8.0
Artists	117	7.5
Actresses	63	3.9
Singers	46	2.9
Editors	34	2 1
Physicians	28	1 7

In addition to these eight, there are lawyers, politicians, religious workers, librarians, scientists, lecturers, explorers, musicians, business women and those interested in home economics. Thus there is a very wide range of activities.

From Table 4 and other data a few conclusions appear warranted. One is that women receive recognition for writing more readily than in most activities. Nearly one half of the 1,582 women whose biographies are given are writers. On the other hand, comparatively few teachers have attained the fame of the type indicated by inclusion in "Who's Who," most of the "educators" included being administrators such as deans and presidents. Indeed, a considerable number of women are holding administrative positions.

The higher education of women was also noted, and it was found that 88 per cent. report training above the secondary school. Of the two groups attending college or college and university, exactly one half of the women report training in women's colleges.

TABLE 5

Type of training	Number of women	Per cent. of women
College	440	27.9
University	216	13.7
Special	466	29.5
College and university	205	13.0
College and special	39	2.4
University and special	23	1.5
None mentioned	190	12.0

This table indicates that few women who do not take advantage of existing opportunities for higher education (beyond the secondary or high school) now attain national fame.

GO TO THE BEE

A Contribution to the Permanence of Aristocracy

By Dr. DAVID STARR JORDAN
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"THE Leisure Classes, the Chief Support of the Nation they adorn"—such was the topic of a remarkable sermon delivered not long ago to an audience of superior people, by the Reverend Vicar of Girlington, England, whose actual name I do not give lest my feeble words fail to interpret his lofty ideals. From the press notices that came under my eye, it appears that the admired and admirable vicar finds his mission in the salvation of British aristocracy through its complete restoration to the ranks of leisure. In his judgment the aristocrats or superior persons serve society best by standing as examples of human perfectibility. This is the end they should seek, through utter surcease from all worry, all effort and all personal hopes and desires.

The vicar would indeed make of the upper classes a group, not of hereditary rulers, but of elect examplars of what humanity may become, a condition to be open to a chosen few to whom is granted release from the sordid side of life. From such relief the great body of the British people are of course excluded—not from any fault or deficiency of their own, but simply because there is not leisure enough to go around. Thus for the chosen the mass must live; the many gather honey for the few to enjoy. But in fairness—and this I take it is the vital part of the vicar's contention—all should have an equal chance in the beginning.

A rationally organized society would then consist of two classes which for convenience the vicar might call the laborers and the leisurers. To the former belongs the capitalist as well as the workman; all indeed who work with hand or tongue or pen or brain labor alike. The leisurer alone enjoys that perfect serenity which comes from fearing nothing, wanting nothing, hoping for nothing. True happiness rests on a division of duty. A natural cleavage lies between those who create and those who enjoy, each condition having its own peculiar delight. Between the two yawns a great gulf which society crosses only at its peril.

The vicar's discourse harks back to the words of Solomon, "Go to the ant; consider her ways and be wise," an injunction inciting alike to modesty and to thrift, two virtues of which the ant is a

model. She knows her place and keeps it. Aspiration goes with aviation; having no wings, she never tries to fly.

But in addressing the leisurer the vicar would modify his text: "Go rather to the bee; consider his ways and be wise." Physically the bee resembles the ant, but his social system is organized on a more exalted basis. With him, the leisure class is unquestionably the chief support of the society it adorns. And now to make clear the vicar's appeal, I find it necessary to amplify the too meager report given in the *Girlington Guardian,* and without holding the speaker closely responsible, I may draw for the moment from the fascinating observations of the noted apiarist of Brussels, Maurice Maeterlinck.

Two salient facts at once appear: first, bee society maintains its own aristocracy, second, its leisurers, having no hereditary claim for distinction, are chosen by lot and by no effort of their own. As the young bees are about to hatch, their faithful nurses construct a few cells of extra size and feed the occupants on a special food, the "royal jelly" of the apiarist. These selected individuals, the "queens," then grow up in an atmosphere of leisure. To produce the harmonious and perfect bee for which the toiling workers exist is the culmination of the apiarian system.

In carrying the analogy into human society, the essential point (as I think the vicar would agree) is that among men as among bees, no injustice shall be done. Leisurer and laborer must both exist, but as both are of one lineage, each should have an equal chance for the great prize of existence. That "the rank is but the guinea's stamp, the man's the gold" is literally true. Royal jelly and a royal cell make the bee-aristocrat. The difference between queen and worker is purely one of bringing up; the two are of the same blood, the queen becomes regal without effort of her own.

By like means human society may breed its aristocrats—so reads the lesson to be learned from the bee. The queen exists not for her own sake, nor by inherited right. Neither should a lord among men, his only true function being to round out the humanity of his fellows, show what man has it in him to be if brought up without work or worry, marred by no trace of struggle, no fear of defeat, by nothing which wrinkles the brow, makes callous the hands, nor hardens the heart! Lacking this perfect ideal, end and aim, humanity can never realize itself.

Perfection, by the very nature of things, is denied the laborer. Yet how vital it is that perfection should exist! Plainly, however, only a few can be leisurers, though in life's grand lottery all may start alike. The needs of the hour call for the "man with the hoe," the woman at the washtub. Some must toil and spin that the human lily may be properly arrayed. Mark, too, the perfect rose,

"its own excuse for being," yet dependent on stem and leaves and roots for very existence. Moreover, its glowing petals are but leaves transformed and perfected. Thus from the lily or the rose one may draw the same lesson as from the bee and the ant.

In his implied criticism of the British aristocracy of the renowned Victorian era, the vicar proceeds with becoming modesty. It would seem indeed presumptuous in the holder of a living, the gift of a gentleman of the county, to say one word in dispraise of conditions as they are. The very essence of organized religion is conservatism.

Yet some one must turn his face towards the light, and every student of history knows that the "Decline of Aristocracy," as defined by one of its illustrious examples, Mr. Arthur Ponsonby, is now imminent. The only way of avoiding decadence is to place aristocracy on a democratic basis, as it were, to open its doors to all, but at the same time keep the passage narrow so that few can enter. "Strait is the gate, and narrow is the way" that leadeth to perfection.

The Victorian system is open to cavil on three sides: it is hereditary: it is open to invasion by wealth, it is used as a reward for achievement.

As for heredity, one easily sees that mere aristrocratic descent does not guarantee a perfect leisurer. "Blue blood" tends to run thin, and in-and-in breeding plays havoc with the human stock as well as with dogs and horses. Furthermore, inheritance smacks of privilege, and the iconoclastic Georgian Age will have none of it, No youth is now willing to follow his father's trade. The son of a tailor no longer sits cross-legged on a bench if fate has taken him early in hand, the son of a non-conformist preacher becomes prime minister—and one never knows *where* it is all going to stop! But any healthy boy, caught young enough, is soon aligned with the customs and opinions of his entourage. Set among gentlemen, nothing is easier than to act like a gentleman! As a matter of fact every wise butler soon acquires a manner as lordly as that of his master, whom he often instructs in the higher etiquette. Frequently he has had longer experience, and has given to items of behavior more serious thought. A sympathetic moisture of the eye and a gentle lowering of the voice in delicate moments may come as natural to him as to a bishop. Stephen Leacock of Montreal, a noted American tourist, gives an amusing account of his call upon an ambassador of the United Kingdom. At the end of a discussion concerning the weather and the future of the Empire, he was still doubtful as to whether he had met the ambassador or his butler. To test the matter, therefore, he slipped a gold sovereign into the hand of his host. The coin was accepted, but in such a detached and dignified

manner that the visitor's uncertainty was not dispelled by his maneuver.

With a "young person," the process of adaptation is even more rapid and sure. The charwoman's daughter brought up as a lady yields to none in ladylike perfection. Napoleon even went so far as to propose that women should have no hereditary rank at all, but content themselves with the title of their consorts. Presumably his experience with the stalwart insistence of his otherwise plebeian sisters whom he had personally ennobled determined his attitude in that regard. But most of us are familiar with the career of the Honorable Lady Burnett, a woman of humble origin as her friends admit—once a milkmaid or (according to traducers) a barmaid, who became through an exalted marriage "the arbitress of the elegances for all the region about her husband's manor house." From the *Morning Post* one learns that "she used, queen-like, to reign; nay, pour at tea in the newest and tightest of white gloves," and with that undefinable *je ne sais quoi* which marks the true aristocrat!

An aristocracy has been defined as "a social superstructure reared on a foundation of bestness." There is but one permanent basis for "bestness." This is implied in the thousand year old motto of the aristocratic Winchester College, "Manners makyth man," or in the modern vernacular, "Handsome is as handsome does."

The vicar, himself of humble birth but aristocratic connections, admits freely that it is too late in the day to lay stress on lineage. We all claim Adam as a forbear, and not one of us has ever had even a single ancestor weak enough to die in infancy. Leisurer or laborer, each has weathered the storm; in that sense, all are noble alike. Genealogists also affirm that we unmixed English people are all of Plantagenet stock, most of us through the first three Edwards, descended from William, Alfred and Charlemagne. Indeed, one eminent authority classes all Englishmen together as the "inbred descendants of Charlemagne," and Charlemagne (as we know) was at the head of a League of Nations, being at once King of France, Emperor of Germany, and Overlord of Europe. Noble blood indeed is ours, but unfortunately so many share it that it can not serve as a test of aristocracy.

Again, large numbers of our so-called nobility have arisen through long years of struggle directed toward that end. Social extrication is a form of hard work, and labor of whatever kind mars the soul as it wrinkles the brow. A furrowed face is of itself a badge of serfdom. A mind too alert, an ambition too urgent, tends to defeat the purpose of social adornment. To diffuse sweetness and light is not an arduous occupation. Indeed to give

thought to it or to make it a result of definite effort is to fail in the most important element. The leisurer who goes down into the East End to mend the manners of the poor would do better to confine himself to awarding the conventional goose and bottle of ale at the happy season of Christmas. Those who have pursued this policy enjoy a devout gratitude heightened by its rarity. If life for the laborer was all ale and goose—or beer and skittles, as vulgarly paraphrased—no one would know his place, and the barriers betwixt laborer and leisurer so carefully built up in the long centuries of England's glory would be completely broken down.

Browning paints the ideal leisurer as a king who "lived long ago in the morning of the world" with a forehead "calm as a babe new born." This is an enchanting ideal, but the further description (so familiar that I need not quote it here) does not fit their lordships of to-day. No one would take it for a portrait of Northcliffe, Carson, or Birkenhead, whose bustling activities keep the realm in turmoil. An aristocracy founded on labor of mind or hand is not a class of leisurers. Like my Lord Bottlebrush and the "Duchess of Draggletail" in Thackeray's satire, however high the circle in which they move, their manifest lack of noble repose only swells the confusion.

Moreover, no genuine aristocracy can be founded solely on wealth. The "bounder-nobility"—as an irreverent press styles them—are noble in their own eyes alone. In an exalted circle money should never be thought of, much less mentioned! The bee queen builds no cells and gathers no honey. No increment of beebread or royal jelly is due to her own activities, or received by inheritance. Queen and environment are alike parts of one system. So it should be with a true aristocracy. No quest of gold, no promotion of enterprise, no regret over the past, no worry for the future, no will to know, no call to govern, no mission to control, no fear of loss, no hope of gain, ought to intrude to break the perfect peace. Kept in place by a reverent society, the Lord of Leisure need only pose as the glint of a sunbeam across the trail of the toilers, merely strew flowers along the pathway of life, in short be like

> Roses in their bloom
> Casting their petals over on the grass
> Over the way the Beautiful must pass.

II

To all this there is an intensely practical side. If aristocracy is to endure (and without it this would be a dreary world indeed) it must be constituted aright. It must reject the false bases of heredity, effort and wealth. It must not be the reward of dis-

tinction, nor be attainable by any competitive examination. Its door should open to all on equal terms, even though straight the gate and narrow the way. The present House of Lords, now swollen to seven hundred members, including almost everybody able and willing to pay the price, will die of its own accord. Let it alone. Let the climbers of yesterday keep on climbing, while we remove the ladders behind them. Let the men who replenish the party treasuries receive in the name of our gracious King—our sole true aristocrat—whatsoever honors their patriotism deserves; but for the good of society let us build a new class in a new way. Should we fail in that endeavor the iconoclasts of the day will cast us all into the melting-pot from which no leisurer returns, an upshot the vicar would sadly deprecate.

To select noblemen by primogeniture is a process comparable to choice by loaded dice; the cast is made before the heir is born. Nothing could be more undemocratic, nothing in reality more unfair to men and women of the race in general. Then let our lords be chosen by lot from among the people at large, let us pick a certain number of babies to be our future leisurers, and feed them on royal jelly[1] or the nearest parallel to that condiment our gracious King may secure.

All expense involved should of course be carried by the people. In the United Kingdom are some 48,000,000 men and women. Let each pay alike; the assessment would then be so small that no one would even notice it. Let each contribute say a penny yearly for social inflorescence—for the perfected blossom of humanity. Such trifling levy would amount in the aggregate to £200,000 sterling, which, judiciously invested, would yield an assured annual income of £10,000, a sum quite adequate to provide for a leisurer throughout life. And the contribution by everybody of one shilling, a tax still absurdly small, would support twelve members of the new aristocracy each year.

The necessary sum once collected, the infant chosen should be entirely healthy, and so attested by a Court physician accustomed to the needs of the leisure classes. It ought also to be a manchild, and its future mate, having no title in her own right, would become a "Lady" by courtesy, even as now the wife of the knighted grocer or jockey is recognized as "Lady" Jones or Atkins because her husband has been touched by the flat of the King's sword and allowed to write "Sir" before his name. Only through an impartial selection may aristocracy and democracy be satis-

[1] This expression is of course purely figurative, because no product of Cross and Blackwell serves our indicated purpose. It is with the general problem of perfected environment that we have to deal.

factorily reconciled; and only when begun before effort, ambition or deterioration has set in can the budding leisurer be adequately trained by nurse and butler in the thoughts and manners proper to a perfect lord. Otherwise, less lovely traits might have become stiffened beyond remedy.

As his lordship grows up, the necessary allowance should come to him in regular sums only. He should never forestall, never hoard, never gamble, never speculate, never go into trade, never run into debt, never have anything left over after Christmas! He should support society as society has supported him; but chiefly he and the lady he may happily choose must remain through life "on the hills as gods together, careless of mankind."

True, as the noble Lord Tennyson once observed, "kind hearts are more than coronets," but there is nothing in the plan to inhibit possession of both at once. A coronet, moreover, may be very becoming as well as very welcome to My Lady. For our new-made lord will never marry for money nor as a rule where money is—all dowry acquired being turned over to the state; and what more exquisite pleasure than that of a young maiden unexpectedly chosen for the high distinction of a coronet! Let us also notice the amazing widening of the possible range of choice when no dowry need be sought.

Doubtless a new title ought to be devised for the consummate flower of leisure. Lord, Duke, Earl, Knight—all these hark back to the discarded emblems of war, "the faded fancies of an elder world." The vicar himself, I believe, was undecided, but the plan developed from hints given in his discourse should not fail just because a suitable name is not immediately forthcoming. The hellenistic term, "Bianthine," "flower of life," would be appropriate, but it seems rather long, used as we are to the abrupt Saxon "Lord and Lady," or the Norman "Sir." "Flovite" *(flos-vitæ)* might do; represented by the letters F. V. it would be a natural contrast to M. P., and a pleasing reminiscence of F. F. V., the designation of certain *Élite* of the United States of America. This again suggests that the word *Élite* itself, a good Norman expression much valued by our Gallic allies, may be the term we are seeking.

In any case, the title selected should in some way indicate one chosen from among many, first among equals, the bloom of existence, the triumph of aspiring democracy reaching the goal of perfection amidst the leaven and the levelling of the commonry. And we hope that the admirable vicar may find ample support in his noble crusade to make the British peerage once more a counsel of perfection.

THE FOOD RESOURCES OF THE SEA

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PRIMITIVE man got his food as his competitors did—that is to say, he picked it up or killed it where he could find it. Very early in his civilized career he ceased to be a hunter and began to cultivate the land; in fact, the beginnings of civilization and of agriculture were contemporaneous. Since that time the pressure of increasing populations demanding to be fed has been a prolific source of human strife. There are not lacking economists who would maintain that the recent catastrophic war in Europe was the direct result of an increasing demand for food on the part of the rapidly multiplying German nation. East, in THE SCIENTIFIC MONTHLY for December, 1921, points out that the agricultural resources of the United States can in all probability not support in reasonable comfort more than two hundred million people and that the present indications are that our population will reach that figure within the next century. Furthermore, we can not count on importing food indefinitely, since by the time our own population reaches its limit, the now scantily peopled parts of the world will produce little or no food in excess of the needs of their own greatly augmented populations. His is but one of many voices warning us that there is a limit to the number of human beings whom the earth can support, and however we may disagree with the various estimates as to what the limit may be, we can not doubt that it exists, and that, historically speaking, we are rapidly approaching it. The purpose of this article is, however, not to consider this question in detail, but merely to point out one source of food of which the possibilities are still largely unrealized.

If we were to-day still depending upon the chase as the main source of our food, most of us would be dead, or, rather, we should never have been born. Yet so far as the oceans, which cover three fourths of the surface of the earth, are concerned, we have made little essential advance over the methods of the primitive fishermen. The flocks and herds of the sea still roam freely in their native haunts, and we cast our lines and nets over their feeding grounds, and catch what we can. Our operations are on a larger

scale, it is true, than those of our predecessors, our tackle is superior, our nets larger and stronger, and, by equipping our fishing vessels with steam or gasoline power, we have enlarged the area we can cover. Once the fish are landed, we have an elaborate system of distribution and marketing, so that cities a thousand miles inland can have fish a day out of the ocean shipped to them in fast refrigerated cars. There is also a little direct utilization of the plants of the sea. In certain parts of the world, notably in China and Japan, and to a less extent in Europe, a few of the algæ are eaten by man or his domestic animals, or gathered to be utilized in some minor industry. But so far as the actual cultivation of the sea's resources as distinguished from their mere exploitation is concerned, we have made only the feeblest beginning. The reasons for this are, of course, the uncontrollability of the sea as compared with the land; its instability; the vastness of the oceans and the relative inaccessibility of much of their area; and especially the difficulty of attempting to control living organisms in the sea, out of man's natural element, as they may be controlled on the land where he is at home. Yet if the demand becomes insistent enough we can not doubt that methods will be devised which will give us the desired results. To question that would be to admit that man has neared the culmination of his evolutionary career and is preparing to bequeath the mastery of the earth to his successor, whoever that may be.

The bulk of the food supply which we have come to expect the ocean to furnish us is animal. Animals that live in the sea are, however, no less dependent upon plant life for their food than are land animals. We all know that the beef we eat is built up from the grass and grain upon which the cattle have fed; and, while there are many animals that feed upon other animals only, sooner or later the cycle goes back to the green plants. This is because the green coloring matter contained in plants is the only substance known that can so combine carbon and water as to form the carbohydrates that are the fundamental materials of which all living beings, whether plants or animals, are constructed. The plants living in the sea are then the equivalents, so far as the life of the sea is concerned, of the land plants. Like land plants, they not only need carbon and water, but certain mineral salts. Of these, those that furnish them with nitrogen and phosphorus are most important, since they are most apt to be present in insufficient quantity and thus to be limiting factors. The plants in the sea are continually using these substances and are continually dying or being eaten by animals. Sooner or later there comes a time when by the death and decay of the plant or animal most of

these materials are returned to solution. Part, however, have been transformed into insoluble compounds and are lying inert in the depths of the ocean. Thus there is a constant loss of nutrient salts. This loss is replaced by drainage from the land, the great rivers carrying constantly into the ocean an almost incredible amount of dissolved minerals in addition to suspended matter.

Another important requirement of plants is light. Plants on land receive the full benefit of the sun's rays as we know them. Plants living under water receive only a portion of the rays that reach the land. Part of the light that strikes the water is reflected, and the part that penetrates the water is gradually absorbed in passing through that medium, the red and yellow rays first, the blue and violet last. This differential absorption is reflected in the curious and well-known vertical distribution of marine algæ according to color—the green kinds growing in shallow water, the browns in an intermediate zone and the reds in the deepest water, although there are, of course, numerous exceptions to this general rule of distribution. Another property of light is that it is refracted by water, and the greater the angle at which the rays strike the water the greater will be the refraction. In the tropics, where the rays are practically vertical, the amount of refraction is insignificant, but in high latitudes, where the rays strike the water at a sharp angle, the refraction is marked, as a result of which the rays are bent into a more nearly vertical direction, thus increasing their penetration in depth and partly compensating for the unfavorable angle at which they strike the water. The penetration is also markedly affected by the amount of suspended matter and the number of microorganisms present in the water. Helland-Hansen was able to show that in the Atlantic Ocean south of the Azores, on a bright summer's day, light is abundant at a depth of 100 meters, still including at that depth a few red rays. At 500 meters the red rays have completely disappeared, but blue and ultra-violet rays are still plentiful, and may be detected at 1,000 meters, but have completely disappeared at 1,700 meters. It is not probable, however, that under the most favorable conditions photosynthesis may be carried on at depths greater than 200 meters.

Temperature is less directly important in the sea than on land since there is no great danger of injurious extremes being reached. Indirectly, its importance lies in the fact that carbondioxide is much more soluble in cold water than in warm, (Fig. 1) and it is probably this, rather than the direct influence of temperature which accounts for the fact that the most luxuriant development of plant life is in the colder waters of the earth.

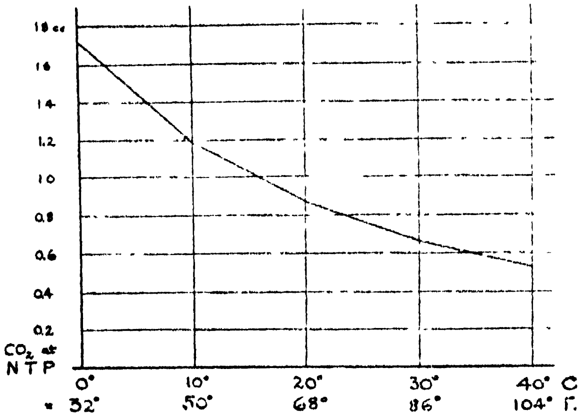


FIG. 1. SOLUBILITY OF CARBON DIOXIDE IN WATER. CUBIC CENTIMETERS OF CO_2 SOLUBLE IN 1 C. C. OF WATER, REDUCED TO NORMAL TEMPERATURE AND PRESSURE

On the basis of habitat, marine plants may be divided into two great groups. On all coasts, and in shallow waters near the coasts, there is usually a conspicuous zone of "seaweed." This is known as the benthos, from a Greek word denoting bottom, because it occurs attached to the bottom on the shelf of shallow water surrounding the coasts. The plants of the benthos are extremely varied and range in size from microscopic to very large, the giant kelps of the northern Pacific sometimes reaching a length of nearly four hundred feet. We are accustomed to think of these plants as algæ, and most of them belong to one or another of the great algal groups, but the most important of all the plants of the benthos is not an alga but a flowering plant, belonging to the pondweed family, and not very distantly related to the grass family, which is the most important economic family of land plants. This is *Zostera marina*, the common eel-grass. *Zostera marina* or some of its near relatives occurs on almost all the ocean shores of the globe, being absent only in the extremely hot and extremely cold portions. It grows in water varying from a little over a meter in depth at low tide, to depths of fifteen or twenty meters in certain clear Mediterranean waters; and in waters varying in salinity from that of the sea water of the open ocean to that of brackish bays and estuaries of less than half full salinity. It prefers mud, but will grow nearly as well in sand. It will not grow, however, where the bottom is composed of loose stones nor where the wave action is severe, and these localities are inhabited by the true algæ. The windrows of dead "seaweed" commonly found cast up on our Atlantic shores are very largely composed of *Zostera*. A few other flowering plants occur in salt or brackish water, but they are relatively unimportant.

The algæ of the benthos occur, as previously stated, in three rather indefinitely limited zones. In the quiet waters of shallow bays we find a great many green and blue-green algæ. Such forms as *Ulva lactuca* and *Enteromorpha intestinalis*, both often called sea lettuce, are typically found in such situations. The branching, feathery masses of *Cladophora* and the thick green felt of *Vaucheria* are also often prominent. The blue-green algæ are entirely microscopic, but often occur in great abundance. A species of *Lyngbya* frequently forms felted mats two or three inches thick and many feet across. Masses of *Spirulina* as large as a dinner plate are common. The plants which grow between tide levels or just below low tide, at places where there is considerable wave action, belong mostly to the brown algæ. Various rockweeds, belonging to such genera as *Fucus* and *Ascophyllum*, are common in northern waters, and the gulfweed, *Sargassum*, is typical of the forms growing in the warmer waters. Below low tide level the great kelps—the Laminarias and their allies—are the largest plants of the ocean, the larger species occurring, however, only in the cooler waters. The algæ of the deeper waters are mainly the reds, and the farther south we go the greater becomes the preponderance of the red algæ. It must be remembered, however, that red, brown, green and blue-green algæ are more or less intermingled at all depths and in all latitudes. All the plants we have been considering are alike, however, in that they occur only near the shores, except in cases where they have been torn loose from their fastenings and carried by currents into the open sea. The Sargasso Sea of the Atlantic Ocean is merely an area outside of the track of the great oceanic currents and therefore constituting a huge eddy in which such material accumulates, growing vegetatively to a certain extent and finally dying and sinking.

If the only marine plants were in the benthos, in spite of the local luxuriance of its growth, the great mass of the ocean would be a desert, incapable of supporting anything like the amount of life which actually exists in it. There is, however, another great group of living organisms, the plankton. The plankton comprises those plants and animals that are neither attached to the bottom nor able to swim against a current, but normally live floating in the water and carried by it from place to place. Some of the animals of the plankton are of rather large size—such, for example, as the Portuguese man o'war and some of the larger jellyfish. Most of them, and all the plants, are microscopic. The plants, in fact, are all unicellular, although the cells are often united into filaments or colonies of various shapes. Two groups of plankton organisms are of special importance: the diatoms and the peridines.

The diatoms are unicellular plants occurring in all waters, but especially abundant in the colder parts of the ocean, growing in enormous numbers in the Arctic and Antarctic regions and reaching in temperate waters their maximum development in the cooler months of the year. They are unicellular organisms, enclosed in two silicious shells, one fitting over the other much as the lid fits the bottom of a pill box. In shape they are extremely varied, and the shells are usually marked with intricate patterns and often decorated with spines and knobs.

The peridines constitute a curious group of unicellular organisms intermediate between plants and animals. Some of them are holophytic or plantlike in their method of nutrition, others are saprophytic, absorbing dead organic material dissolved in the water, some are parasitic in the body cavity of small animals, such as copepods; a large number are holozoic, capturing and ingesting their food just as animals do. The peridines very largely replace the diatoms in the tropical seas, and in temperate waters attain their maximum numbers in the warmer months when the diatoms are at a minimum. This seasonal distribution is very possibly correlated with the diminution of the carbon dioxide content of the warmer waters. The peridines may be naked, or provided with a simple or elaborate armor of cellulose, the same material as that of which plant cell walls are composed. Whether armored or not, they are always provided with two flagella, one, hair-like, which trails behind them, the other a ribbon-like undulating structure typically encircling the body in a special groove provided for it and giving to the organism a rotatory motion.

In spite of their minute size it may fairly be said that the diatoms and the holophytic peridines are to the ocean what the grasses are to the land. What they lack in size is more than compensated for by their extreme abundance and rapidity of reproduction. Under favorable conditions hundreds of thousands of them may exist in a liter, so that the water is distinctly colored and is almost soupy to the touch.

A third group of important plankton organisms, entirely holophytic in their nutrition, is known as the *Coccolithophoridae*. These are brown-pigmented forms secreting very regular calcareous shells and occurring in the warmer parts of the open ocean. Most of them are extremely minute and while they are known to occur in extremely great abundance at times, because of their small size little is definitely known about their distribution or relative importance.

In addition to these groups of organisms, the zoospores and gametes of algæ are liberated in enormous number at certain seasons of the year, and add their contribution to the food supply of

the plankton, while there are numerous brown and green flagellates belonging to other than the three groups mentioned.

The phytoplankton exists everywhere at the surface of the ocean and for a considerable depth below the surface. Certainly it is fairly abundant as far down as a hundred fathoms in those parts of the ocean where the light approaches the vertical. It is, however, much more abundant near land than in mid-ocean, mainly because the organisms near land are in more immediate contact with the nutrient materials washed from the land into the sea, and tend to exhaust the supply before these materials reach the open ocean. The ratio between the number of plankton organisms near land as compared with the number in the open seas has been given as fifty to one, but this estimate, for reasons which will be apparent later, is probably much too high.

It is not enough to know life in the ocean qualitatively. It was long ago realized that it must be analyzed quantitatively. The earliest quantitative studies were those of Hensen, beginning about 1880, and modern work on the problem may be said to begin with him. He devised the forerunner of the present-day plankton net and attempted to account for the production of the sea by his collections. His nets missed all the smaller organisms and failed to secure many of the larger ones. Hensen realized this and attempted to allow for it in his calculations but his results were necessarily very imperfect. He succeeded in imparting new impetus to such studies, however, and deserves the credit due to a pioneer worker in a difficult field. The amount of food required by the animals of the sea is so much in excess of the amount shown to be produced by these early methods that Pütter (1907-1909) argued that the nutrition of marine animals was on an entirely different plane from that of land animals, and that a large number of them, especially the smaller ones, absorbed dissolved organic matter directly from the water without the mediation of plants. Pütter's arguments have not been generally accepted and more recent studies have invalidated many of them. Nevertheless, it is possible that something of this sort is more general than we realize. Mitchell has recently (1917) reported on experiments strongly indicating, although perhaps not proving, that so highly organized an animal as an oyster can utilize dextrose dissolved in sea water, transforming it into glycogen and storing it.

In 1911 Lohmann showed that many of the organisms that pass through the plankton net may be secured and studied by the use of a centrifuge. This, again, marked a great advance. He showed that these smaller organisms, for which he proposed the convenient term "nannoplankton," existed in enormous numbers in parts of the sea which the net collections seemed to show were barren,

and found that certain animals—*Appendicularia* e. g.—were very efficient collectors of these minute forms, sometimes feeding on them almost exclusively. Gran reports a similar experience in the Straits of Gibraltar. Net collections showed very little plankton in the water, but the stomachs of *Salpae* when examined were found to be crammed with forms too small to be retained by the nets. Even centrifuging fails to get many of these forms since they are often lighter than water or as light, or are so delicate that the operation destroys them. Allen has devised a dilution culture method similar in principle to those used in making bacterial counts. He adds to a quantity of filtered sea water a few drops of a nutrient solution, sterilizes it, and adds to it a known quantity of the sea water to be investigated—say, one cubic centimeter. After thorough shaking, this is poured into about a hundred sterile flasks and put in a north light for a few days. The flasks are then examined and the organisms that have developed in them identified, and the number of different kinds that are found in each flask are recorded. A given species is recorded only once from each flask and since at least one individual of the species must have been introduced to permit such development, the count is still too small. By actual experience this gave results of 464 organisms per cubic centimeter or 464,000 to a liter. Bacteria were disregarded. The centrifugal method applied to the same water gave a count of 14,450 to a liter. Allowing for duplication in some of the flasks and for the failure of many forms to develop under laboratory conditions Allen concludes that a count of 1,000,000 organisms per liter would be conservative. That is, one organism to each cubic millimeter. Assuming an average size equivalent to a sphere with a diameter of five microns, that is not excessively crowded, as the diagram will show. (Fig. 2.)

FIG. 2. COMPARATIVE SPACE OCCUPIED BY AN ORGANISM 6 MICRONS IN DIAMETER IN A CUBIC MILLIMETER (1/1,000,000 LITER) OF WATER

In this country, Moore, followed by Grave, attempted to calculate the "food value" or areas of water on the basis of similar plankton counts, working with special reference to the nutrition of oysters. They found out what organisms occurred in greatest numbers in the oysters' stomachs, studied the rate of feeding and then proceeded to collect and analyze samples of water over actual or potential

oyster beds, finding out just how many of these organisms occurred to the liter. They then carefully calculated the volume of each organism and by multiplying the volume by the number of times a given organism occurred in a unit volume of water and adding the totals, the "food value" was secured. This method gave much valuable information, but the results can not be regarded as final for several reasons. For one thing, organisms differing so widely as diatoms and peridines are not comparable on the basis of their volumes, as has been pointed out by Brandt and Juday. Again, in a locality where oysters are not naturally growing, their introduction often materially increases the supply of food, since their shells form substrata and their excreta help in the nourishment of numerous food organisms. Finally, they took no account of the food value of the nannoplankton nor of the detritus, which may be very considerable.

The most elaborate attempts to calculate the production of the sea have been those of the Danish biologist Petersen and his associates. As a result of their studies, these workers have come to the conclusion that the plankton plays a very small part in the nutrition of the animals of the sea and that the fundamental food of all marine forms in northern waters at any rate is the "dust-fine detritus" of the sea bottom, derived primarily from the eel-grass, *Zostera*. As an indication of the degree of progress which

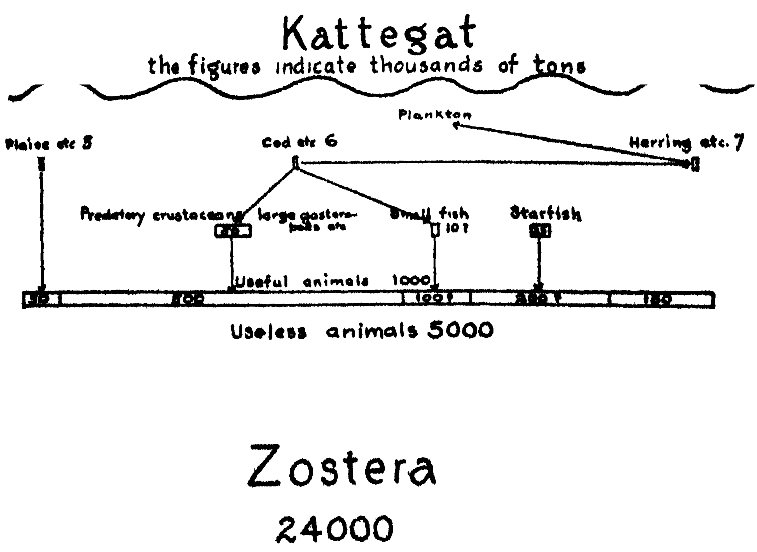


FIG. 3. ANIMAL LIFE IN THE KATTEGAT DERIVED FROM ZOSTERA, AFTER PETERSEN

these workers have made, the preliminary conclusions in the life in the Kattegat may be cited. The Kattegat is the rather shallow body of water between eastern Denmark and Sweden, having an extreme length of 150 miles and an extreme breadth of about 90 miles. It is assumed that about half of the total amount of *Zostera* annually produced in this area is washed elsewhere by the currents. The balance, estimated at 24,000,000 tons, serves as the basis for the animal life of the area. (See chart, Fig. 3.) The useless animals, that is, those that are of no value to man and do not serve as food for fish, feeding directly on the Zostera, amount to about 5,000,000 tons. Useful animals, mainly those capable of serving as food for fish, are estimated at 1,000,000 tons. These are not all utilized by food fish, however. Starfish account for perhaps 200,000 tons; 500,000 tons are eaten by the larger gasteropods and crustaceans, of which only a part are consumed by fish; while plaice and other flatfish consume about 50,000 tons, producing 5,000 tons of human food annually. Cod are much less economical, since they get their food at third hand, so to say, and each ton of the 6,000 tons produced annually represents about one hundred times as much of the original synthesized organic food. On the other hand, the cod help to keep down the predatory gasteropods and crustaceans. The herring is the most important food fish feeding on the plankton, (mainly on copepods) and it in turn is eaten by the cod. Perhaps the most striking feature brought out by these figures is the comparatively trifling amount of human food finally produced from such a large amount of organic material.

So much, then, for the life naturally existing in the ocean. How may our utilization of it be more intelligently directed? Obviously the most economical use of it as food would be for man or his domestic animals to eat it directly. So far as the use of algæ as food for human beings is concerned, we cannot expect, for the present at least, any considerable increase over the insignificant amount now consumed in the United States. In some countries algæ have been used as food for stock for centuries, and recent experiments have indicated that cheap and effective treatments may make possible a substantial increase in such use. It has recently been shown that the kelps exhibit wide variation in their carbohydrate as well as in their iodine content during the growing season and future utilization, to be profitable, must take such fluctuations into account so that the plants may be harvested at the proper season. We would not think of doing anything else in the case of a land plant. And it may be mentioned in passing that the old method of burning kelps for potash and iodine content

cannot be regarded as anything but a wasteful process even when temporary conditions permit it to compete with other sources of these products, as during the world war. Recent experiments in Sweden have suggested that dry distillation will yield, not only the potash and iodine formerly sought, but numerous other products, including illuminating gas, acetic acid, methyl alcohol, formic acid, acetone and creosote.

Since, however, man prefers to harvest the plant life of the sea indirectly, those animals which feed directly on the plants are able to increase with less waste and at a more rapid rate, considered in total populations, than those which feed on other animals. Most of our food fish, for example, feed on smaller fish; these in turn feed upon small crustaceans and the latter eat the microscopic plants and detritus, so that in many instances the fish we eat are removed three or four steps, perhaps more, from the original food source. This is more significant than may seem apparent at first glance, since it involves an enormous waste. Before any organism can grow, the energy needed merely to live must be supplied, and by the time a crustacean is eaten by a minnow, or a minnow by a food fish, it will, on the average, have consumed a quantity of food several times its own weight. These facts are well brought out in the diagram and statistics of Petersen, previously quoted. The edible shellfish, however—oysters, clams, mussels and the like—feed for the most part directly on the marine plants and this is one reason why the extension of the shell fisheries represents so much promise.

The carp is one of the few edible fish which lives directly on vegetable food. In the United States most people do not, it is true, regard this species as particularly edible but since it is largely eaten in Europe and raised for the purpose, it will serve as an excellent example of what such a fish may produce. The statistics on this fresh water fish are particularly valuable because they are not subject to the sources of error which hamper attempts to measure the productivity of the sea. The amount of fish produced in carp ponds has been calculated as ninety-five pounds on the average each year per acre. Brandt calculated the productivity of Kiel Harbor as eighty-nine pounds per acre annually, but the latter figures are much less exact. The average yield of beef on good land in the United Kingdom is seventy-three pounds per acre annually. The beef is much superior in food value, pound for pound, but it is also much more costly to produce. There are many inlets of the sea where conditions are almost as readily controllable as they are in the fresh water ponds. Such, for example, are the shallow enclosed sounds on the Atlantic coast of the United States

—Great South Bay in Long Island, Barnegat Bay in New Jersey, Albemarle and Pamlico Sounds in North Carolina and parts of Chesapeake Bay. These enclosed areas are at present producing a great deal of human food, but only a small part of what they might produce under proper management. On a larger scale, the Baltic and North Seas of Europe are similar regions where, if not sea culture, at least an intelligent harvesting of the seas' resources is yearly becoming more possible because of the careful studies which have been made by the English, German and Scandinavian biologists, whose countries are chiefly interested in the matter.

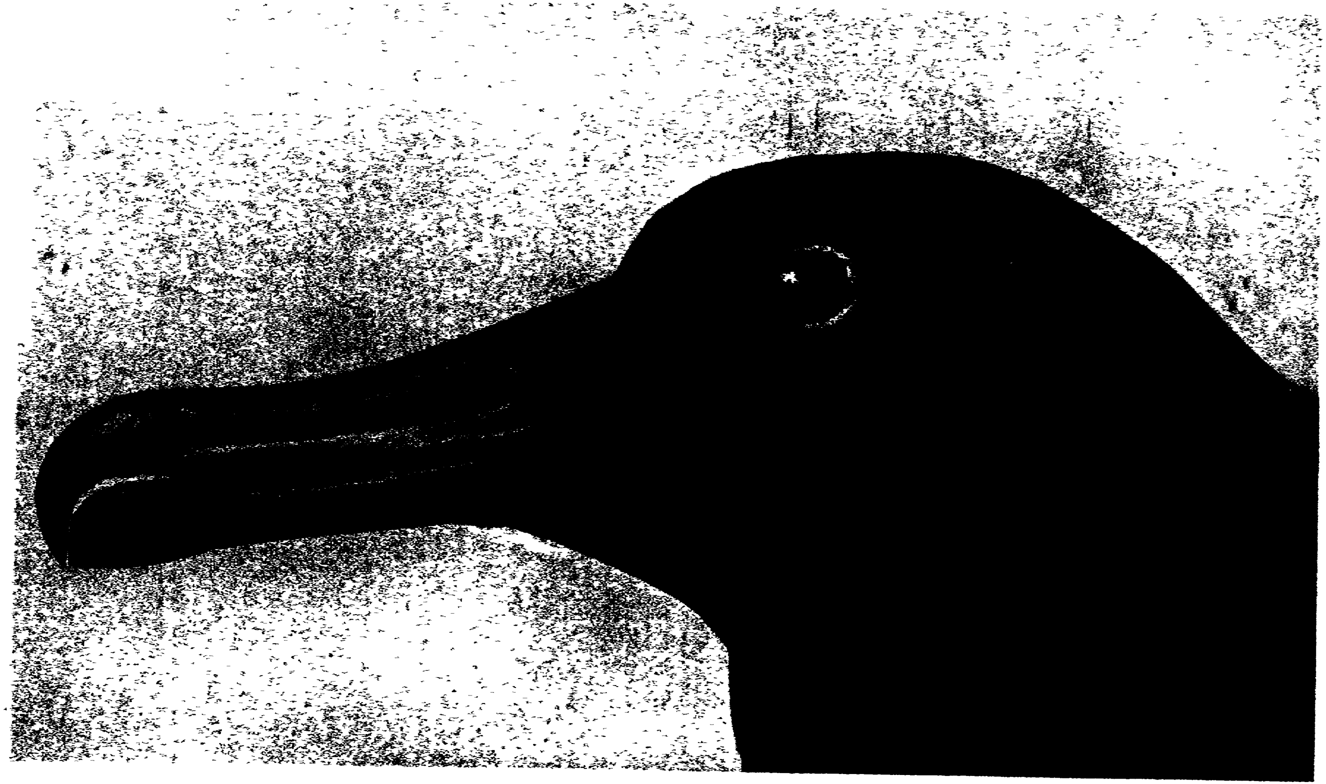
Before we can expect to make substantial advance we must have a much more comprehensive knowledge of the ecology of the sea than we have at present. For example, we may class the animals of the sea roughly into those which are valuable to man and those which are not, but when it comes to determining to which of these classes any particular species belongs, difficulties arise. The difference which direct and indirect utilization of food makes has already been pointed out. Some useful species which get their food at second or third hand, that is, by eating other animals, prey largely on forms that would not otherwise be converted into human food; some, on the other hand, eat species that are good human food. Thus, drumfish are good human food, but they may at times consume large numbers of oysters which are still more valuable to man than they are. Starfish, which are utterly useless forms, also attack oysters, but this case offers no perplexities. A very large number of animals are useless in the sense that they occupy space and consume food which might otherwise be utilized by useful species. The snails, sponges, sea anemones and some of the mussels of our northern waters belong to this group. However, in the case of most marine animals only a complete account of their life histories, together with the life histories of their associated forms is sufficient to enable us to know whether they are, in the long run, valuable or harmful from the human standpoint and whether it would be wise for us to attempt to overturn the balance which we find them maintaining in nature.

Another phase demanding careful study is the effect on the marine life of the waste materials which are constantly being poured into our waters, especially in the vicinity of our great cities. So far as industrial wastes and oil are concerned, the effect is wholly bad, and the questions at issue are: How much of this discharge is necessary? How can the pollution best be restricted to the necessary minimum? The sewage problem is more complex. The addition of large amounts of rich nitrogenous fertilizing material to our waters could be made a great source of wealth if it were

properly utilized, and even under our present hit or miss methods it results in a marked enrichening of the marine flora in favored localities. On the other hand, the danger of disease transmission is so well recognized and is illustrated by so many striking examples that large areas of sewage-polluted waters are eliminated as sources of food in whole or in part. How to utilize this valuable asset without endangering public health or spoiling the recreational value as well as the food value of our coastal waters is one of the biological problems of our day.

Finally, it may be reiterated that shellfish culture offers the most immediate hope for effective utilization of the sea's resources. The economy of direct utilization of plant food by these animals has been emphasized. Most shellfish, like land crops, stay where they are planted. Even the scallop, which can swim about after a fashion, is restricted in its movements and could readily be controlled. Oyster culture is already a great and important industry but it has not nearly approached its possibilities. Clam culture is still in an embryonic stage and scallop culture has as yet merely been suggested. When some of the problems confronting the establishment of these industries have been solved we may hope to have acquired additional information concerning the ecology of the sea which will help us in our approach to the more difficult problems of the future.

It is recognized that there are numerous economic phases involved in attempts to increase the productivity of the sea, but consideration of these would be beyond the scope of this paper. When social and economic forces demand additional food at reasonable prices, the biologists must be prepared to show where and how this may best be obtained.



HEAD OF THE SOOTY ALBATROSS

OUR GREAT ROVERS OF THE HIGH SEAS— THE ALBATROSS

By Dr. R. W. SHUFELDT
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IN going over the literature devoted to ornithology, we find that but a small part of it refers to the birds known as Albatrosses. Alexander Wilson, the famous American ornithologist, never once mentions any of them in his work; and Audubon, who had splendid opportunities to study them in nature as well as in museums and private collections, touched upon those he had heard of, or studied skins of, in the lightest possible manner. In volume VIII of his work in my library, I note that he devotes but a single paragraph to the description of the genus (Diomedea). Apart from the description of characters, he gives but three and a half lines to the Yellow-nosed Albatross; a few lines more to the Black-footed Albatross, and four lines and a half to the Dusky Albatross—the last-named being the only one he figures. He was indebted to a "Mr. Townsend" for skins of all these species, the latter having collected them "not far from the mouth of the Columbia River."

As to the Black-footed Albatross, Audubon says: "It is clearly distinct from the other two described in his work, namely, the Dusky and the Yellow-nosed; but I have received no information respecting its habits. Not finding any of the meagre notices or descriptions to which I can refer to agree with this bird, I have taken the liberty of giving it a name, being well assured that, should it prove to have been described, some person will kindly correct the mistake." He named it *Diomedea nigripes,* the Black-footed Albatross, and it is the name we have for the species to-day.

In the last A. O. U. "Check-List" (1910), in addition to the bird just mentioned, we recognize four other species as belonging to the North American avifauna, namely, the Short-tailed Albatross (*D. albatrus*); the Laysan Albatross of Rothschild (*D. immutabilis*), and the Yellow-nosed and the Sooty Albatrosses (*T. culminatus* and *P. palpetrata*). These are all Pacific Ocean birds, though the Yellow-nosed species is said to have "accidentally occurred in the Gulf of St. Lawrence."

Personally, I do not recall ever having seen an Albatross in

nature; only a few of our ornithologists have, and, as just stated, neither Wilson nor Audubon fared any better. However, I have carefully examined quite a number of them in the collections of the United States National Museum; and not long ago, Dr. Charles W. Richmond, Assistant Curator of the Division of Birds of that institution, kindly loaned me the head of a specimen of the Sooty Albatross. It had no artificial eyes, and apparently was simply a head and nothing more—not even bearing any label or history. This head I photographed on side view, reducing it about one fourth, furnishing the print with an eye. That print is here reproduced as an illustration to my article.

Audubon's description of the beak of this species is so obscure as to be of but little value.

The plumage of the head—a rich snuff-brown—is soft and composed of fine feathers, and there is a narrow white stripe of short feathers surrounding the posterior half of the eye-lid on either side of the head. The beak is glossy black and formed as shown in the cut.

There is in existence a wonderful literature on the Albatrosses, especially when we consider how few species there are comparatively speaking. The old figures of them in the works are often very crude; while, upon the other hand, some fine photographic reproductions in different works are wonderfully fine and of great value. Among these are the remarkable photographs obtained by the Hon. Sir Walter Rothschild of the immense numbers of the Laysan Albatrosses, nesting on the island of that name; of the dreadful practice of carting away the eggs of that species, taken at the same place, and many others. Then Mr. Dudley Le Souëf, Director of the Melbourne Zoological Garden, has furnished us with a fine photograph of the White-capped Albatross on its egg, which latter, according to Professor Moseley, is held in a sort of pouch to be found between the legs of the bird.

Some species of these birds have a "tip to tip" measurement of the wings of no less than eleven feet and a few inches. It is a well-known fact that in the southern seas, where sailors have fallen overboard, they have been attacked in the water by one or more of these giants of the feathered race, and a poem on an incident of this sort would quite offset the experience of the ancient mariner who shot the albatross, which furnished Coleridge with the material for his famous verses.

The marvelous flight of one of these birds has been graphically described by Mr. Froude, who tells us that "the albatross wheels in circles round and round, and forever round the ship—now far behind, now sweeping past in a long, rapid curve, like a perfect skater on an untouched field of ice. There is no effort;

watch as closely as you will, you rarely or never see a stroke of the mighty pinion. The flight is generally near the water, often close to it. You lose sight of the bird as he disappears in the hollow between the waves, and catch him again as he rises over the crest; but how he rises and whence comes the propelling force, is to the eye inexplicable: he alters merely the angle at which the wings are inclined; usually they are parallel to the water and horizontal; but when he turns to ascend or makes a change in his direction, the wings then point at an angle, one to the sky, the other to the water.''

The bird of this group usually referred to in prose or poetry is the Wandering Albatross (*D. exulans*); and it is said that specimens of it have been collected having an alar extent of no less than twelve feet. It is a bird with extraordinary power of flight, and Professor Hutton has well described the remarkable power these birds possess in that direction. ''Suddenly he sees something floating in the water,'' says this authority, ''and prepares to alight; but how changed he now is from the noble bird but a moment before, all grace and symmetry! He raises his wings, his head goes back, and his back goes in; down drop two enormous webbed feet, straddled out to their fullest extent, and with a hoarse croak, between the cry of a raven and that of a sheep, he falls 'souse' into the water. Here he is at home again, breasting the waves like a cork. Presently he stretches out his neck, and with great exertion of his wings runs along the top of the water for seventy or eighty yards, until, at last, having got sufficient impetus, he tucks up his legs, and is once more fairly launched in the air.''

Another distinguished British writer on this subject, Professor Moseley, in describing their mating habits informs us that ''when an albatross makes love, he stands by the female on the nest, raises his wings, spreads his tail and elevates it, throws up his head with the bill in the air, or stretches it straight out forwards as far as he can, and then utters a curious cry. . . . Whilst uttering the cry, the bird sways his neck up and down. The female responds with a similar note, and they bring the tips of their bills lovingly together. This sort of thing goes on for half an hour or so at a time.''

There is great danger of the entire genus of Albatrosses becoming entirely extinct in the comparatively near future, and for several very good reasons. In the first place, many are shot and killed by passengers and others from the decks of vessels of all descriptions sailing on the high seas. This practice claims its quota every year, and no use is ever made of the poor birds thus ruthlessly slain. Again, many are caught with hook and line, but

these are usually released after being hauled aboard and giving an exhibition of their walking powers on the deck of the vessel. Another practice leading to their extinction—outranking all the others—is seen in the wholesale collection of their eggs for the markets of the western coasts of the Americas. The eggs used to be gathered, and still may be, on their breeding grounds, more particularly on the Island of Laysan, by the cartload, none being left for the perpetuation of the species. At least this was not looked out for in the early days of this most reprehensible trade. Whether it is still going on I am unable to say; but should it be, steps ought to be taken to bring it to an end.

In our bird fauna, the nearest relatives of the Albatrosses are the Fulmars, the Petrels and Shearwater. All these species possess the peculiar anatomy of the external nostrils—being designated in the vernacular as the Tube-nosed Swimmers, while in technical science the name *Tubinares* stands for the group.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson

Science Service

RELATIVITY AND THE ECLIPSE

On September 21 the theory of relativity was put to the proof. After the results of the photographs then taken have been measured we may perhaps know whether Einstein is to be ranked with Copernicus and Newton, among those who have revolutionized man's conception of the universe, or whether he will be regarded merely as the author of an ingenious mathematical theory of limited applicability to reality

For the last three years the theory of relativity has been the topic of lively discussion extending far beyond the scientific circle, for the public realized that some interesting issues were somehow involved in its incomprehensible mathematics. More than a thousand books and uncountable articles have been published on Einstein; all sorts, *pro* and *con*, physical and metaphysical, experimental and speculative, serious and frivolous Prizes have been offered for explanations in ordinary language. Personal, political, religious and racial passions and prejudices have been aroused. Einstein was the first German scientist to be welcomed since the war, in England, France and the United States, but in his own country he has to go into hiding to escape assassination by the junkers.

It is a remarkable example of how the progress of science may continue in spite of political conflict that during the world war Einstein should have sat quietly in his study in Berlin thinking out his theory and that during the world war English astronomers should have been quietly studying his work and preparing to put it to the test at the earliest opportunity.

This opportunity came on May 29, 1919, when there was a total eclipse of the sun. For Einstein had predicted that when the stars about the darkened disk of the sun were photographed they would appear as though pushed out of their positions This is one of the consequences of his theory of relativity, which is designed to supplant, or at least to supplement, Newton's theory of gravitation.

According to Einstein, a ray of light from a star passing close by a heavy body like the sun is drawn out of its straight course a little, somewhat as though it were a stream of material particles, but to a greater extent than Newton's law would allow for. To an astronomer looking up at the star along this crooked path and not making allowance for the bend, it would seem that the star had been moved away from the sun a minute distance (1 74 seconds of arc). Of course this effect is the same at all times, but it can only be observed when the sun's disk is completely shadowed from us by the moon's coming between.

So the British astronomer royal, Professor Eddington, sent out two eclipse expeditions in 1919 to points where the eclipse could be observed, one to the west coast of Africa and the other to the east course of Brazil. When he came to develop and measure up his photographs, he found that the stars about the darkened sun were displaced in the direction and close to the amount predicted by Einstein.

This was good evidence in Einstein's favor, but scientists are cautious creatures and not all of them

World Wide Photos

THE WESTERN AUSTRALIAN ECLIPSE PARTY

The members of the eclipse party, photographed prior to their departure from Perth, Western Australia, for Wallal. Standing, left to right: J. Clark Maxwell, H. L. Quick, J. Hargreaves, J. P. C Hoskinds, Dr R. J. Trumpler, J J Dwyer, C. Nossiter, V J Mathews, C. S. Yates, Dr. J H. Moore, G. M. Nunn. Sitting: Miss Chant, Mrs. Adams, Dr. C E Adams, Mrs. Campbell, Dr. W. W Campbell, Mrs. Chant, Dr. C. A. Chant, A. D. Ross and Dr. Young.

were ready to accept so startling a theory as this without further confirmation. The weather was very cloudy in Africa, and the only good photograph obtained at the South American station was one taken with a four-inch lens and showing seven stars around the sun.

But there has been no other total eclipse observable till this year and this is not so good a one There were no bright stars near the sun, in fact only one visible to the naked eye among those close enough to the sun so that their displacement could be measured. But there were four or five faint stars that may have been caught on a sensitive plate with a good telescope.

Unfortunately too, the eclipse occurred in a highly inconvenient part of the earth Its track was along the Indian Ocean and through the heart of Australia where there are no observatories and few people. The best point was on Christmas Island, lying west of Australia and south of Java This island only measures eight by twelve miles and has a population of about 250, according to the latest census. But it was selected by the British, German and Dutch expeditions for it was in the middle of the track of the eclipse. The dark ness there lasted five minutes and as tronomers can do much in five minutes. It appears, however, from cable despatches that the weather conditions were bad. An expedition from the Lick Observatory, California, was stationed on the west coast of Australia, and the Observatory of Adelaide sent a party into the arid interior of Australia, which involved five weeks of travel by camel train but which was pretty certain to get cloudless weather. In Australia the weather was favorable.

If the astronomical expeditions now in the field bring home confirmation of the results of the eclipse of 1919, then we may have to get used to all sorts of queer ideas, besides crooked beams of light in empty space. We may have to give up the force of gravitation and the ether and the constancy of mass and the distinction between matter and energy. We may get to talking about the curvature of time, the weight of heat, kinks in space, atoms of energy, four dimensions, world-lines and a finite universe We may be called upon to come to conceive of arrows that shrink and bullets that get heavier the faster they travel; of clocks that go slower the faster they travel and of a future that turns back and tangles itself up in the present.

TANGLING UP THE TIME LINE

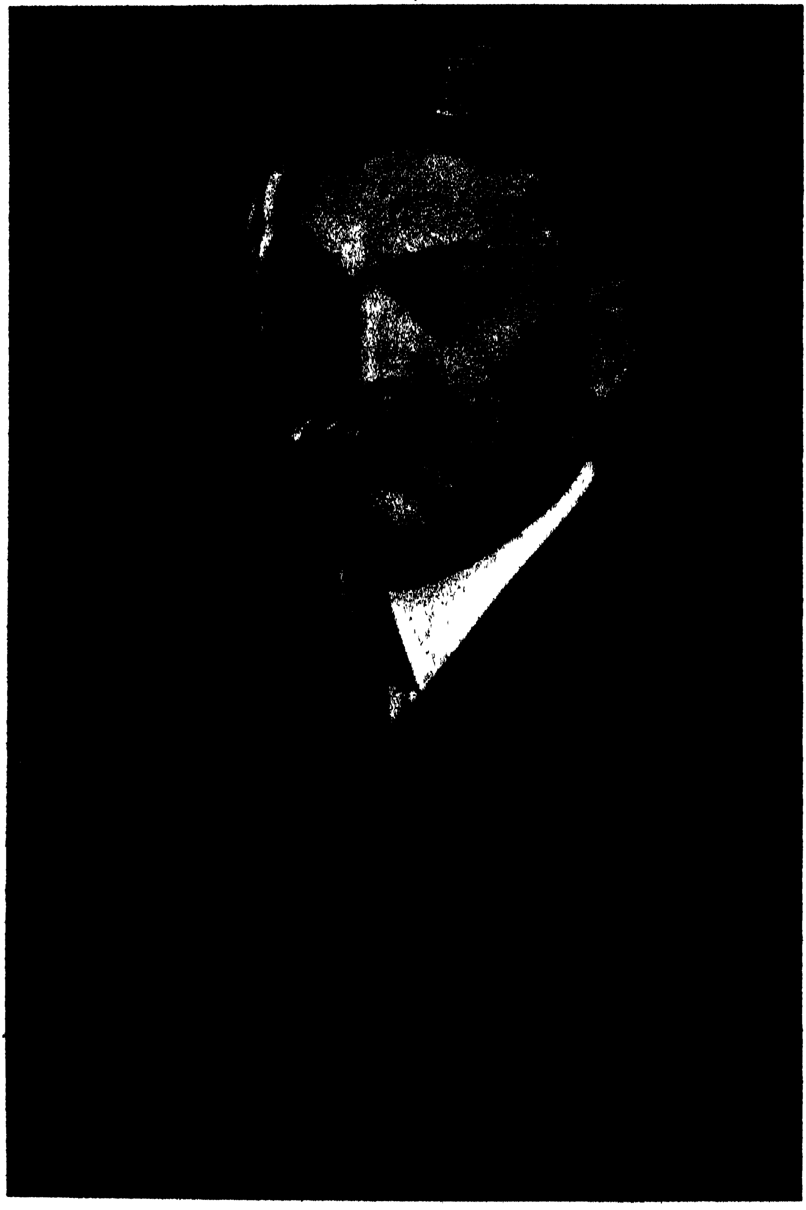
Einstein's theory of relativity is like a magician's bag There seems to be no end to the queer things that can be pulled out of it. The more it is studied the more paradoxical it appears.

The latest thing I have seen is the queerest, the idea that the future may get tangled up in the present or even in the past. It is all worked out mathematically in a book just translated from the German, Weyl's "Time-Space-Matter." Too mathematical for most of us, but the point in plain language is this:

Here is a line representing the course of time extending from the dim past into the indefinite future.

Past Future

The present is the point where I stand, looking both ways like Janus but not seeing any end in either direction. I am continually moving or being moved straight along the time road from left to right. Every instant I step from the past into the future. Every instant a bit of time is taken from the future and added to the past, though neither gets any smaller or larger since both are infinite. The past time and the future time are permanently separated by the moving present where I am and



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PRESIDENT SAMUEL W. STRATTON

Director of the Bureau of Standards since its establishment in 1901, now elected president of the Massachusetts Institute of Technology.

there seems no chance of the two kinds of time ever getting mixed up for they extend in opposite directions

But wait—here's a disconcerting idea. If I roll up the paper I can make the future touch the past. I can overlap them. I can put A.D into B.C. and what becomes of chronology then?

We are used to this curving of apparently straight lines in space ever since 1492 when men found that they were not living on a flat earth but on a sphere If I travel straight east from this town I shall eventually come back to it from the west How far I shall have to go depends upon where I live. If my home were on the equator, I should have to travel 25,000 miles to get to my starting point If it were near one of the poles, I could do this astonishing stunt in the course of a morning's walk.

Now, according to Einstein, the time line is like the space lines. The framework of the world is measured by four dimensions, three of space and one of time, namely, the up-down, right-left, to-fro, past future lines. But these are not rigidly fixed They may be bent and distorted like a bird cage that has been twisted and crushed, though every wire remains intact and connected to the other wires just the same.

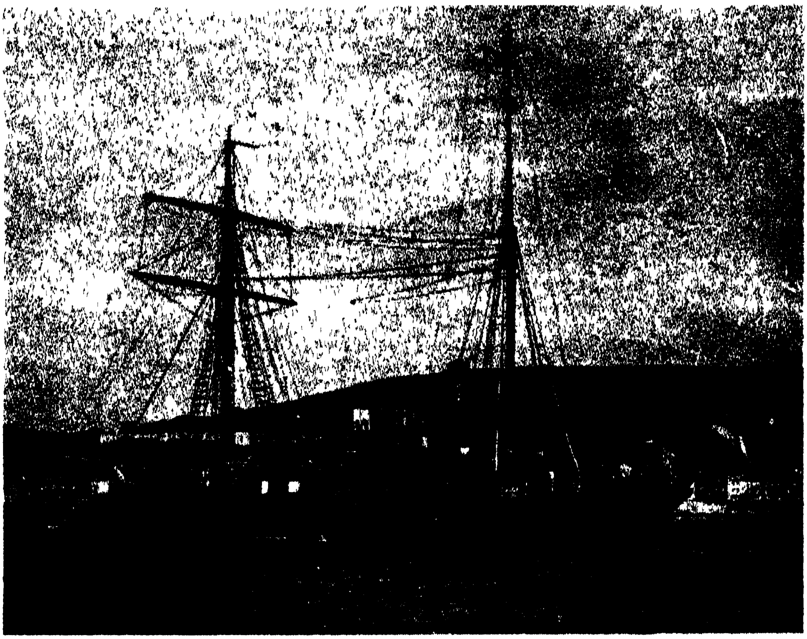
Wherever there is a bit of matter, wherever there are electrical or magnetic forces, there the time and space lines are more or less distorted Einstein, reasoning from this idea, saw that a ray of light from a star, passing close by a heavy body like the sun, would not travel straight, but would be bent a little out of its course. The eclipse of 1919 brought the first chance to test Einstein's idea, and the astronomer royal of Great Britain went to Brazil and took a photograph of the shadowed sun and seven stars about it. And the seven stars seemed shoved out of their customary places just as if in the region around the sun the space and time were puckered up in the way Einstein said they were. When the eclipse of September 21, 1922, came, eight parties of astronomers were on the watch to see if the observations of three years before were confirmed

We have not heard their verdict yet, but, if their photographs measure up according to Einstein formula we shall have to get accustomed to the idea that time—like the tariff—is a local issue, that time measurements like space measurements are relative, not absolute, and that we are not sure of the constancy of our standards of measure in either case When two things happen in our presence we may be pretty sure which comes first. But if one event is here and another in Mars we can not be sure about priority with any conceivable system of clocks and signals. What seems past from one standpoint may seem future from another, for the time line may not run straight. Is your present condition in any way the result of your future actions? Can the light of a match be seen before the match is lit? Such a thing is conceivable in the generalized theory of relativity though, like most other conceivable things, it does not occur or is never known to occur in reality. But it is hard to get used to this strange new notion that the future may curl around in some sort of a circle and so come into the past.

Did I say "new"? It was a slip of the pen. For the idea is old. I open a volume of Egyptian antiquities and I see carved on a monument of the Pharaohs a serpent with its tail in its mouth, the symbol of eternity, of which time is a segment. But what the Egyptians merely guessed at Einstein is putting to the proof.

HOW THE CHEMIST MOVES THE WORLD

THE chemist provides the motive power of the world, the world of man, not the inanimated globe.



World Wide Photos

THE *QUEST* AT PLYMOUTH

The *Quest*, the vessel of the Shackleton-Rowett Antarctic Expedition, on its arrival in Plymouth Harbor on September 16, after the expedition on which it embarked on September 17 of the previous year

Archimedes said he could move the world if he had a long enough lever. The chemist moves the world with molecules. The chemical reactions of the consumption of food and fuel furnish the energy for our muscles and machines. If the chemist can only get control of the electron, he will be in command of unlimited energy. For in this universe of ours power seems to be in inverse ratio to size and the minutest things are mightiest.

When we handle particles smaller than the atom, we can get behind the elements and may effect more marvelous transformations than ever. The smaller the building blocks, the greater the variety of buildings that can be constructed. The chemistry of the past was a kind of cooking. The chemistry of the future will be more like astronomy; but it will be a new and more useful sort of astronomy such as an astronomer might employ if he had the power to rearrange the solar system by annexing a new planet from some other system or expediting the condensation of a nebula a thousand times.

The chemist is not merely a manipulator of molecules; he is a manager of mankind. His discoveries and inventions, his economies and creations, often transform the conditions of ordinary life, alter the relations of national power and shift the currents of thought, but these revolutions are effected so quietly that the chemist does not get the credit for what he accomplishes, and indeed does not usually realize the extent of his sociological influence.

For instance, a great change that has come over the world in recent years, and has made conditions so unlike those existing in any previous period that historical precedents have no application to the present problems, is the rapid intercommunica-

tion of intelligence. Anything that anybody wants to say can be communicated to anybody who wants to hear it anywhere in all the wide world within a few minutes, or a few days, or at most a few months In the agencies by which this is accomplished, rapid transit by ship, train or automobile, printing, photography, telegraph and telephone, wired or wireless, chemistry plays an essential part, although it is so unpretentious a part that it rarely receives recognition For instance, the expansion of literature and the spread of enlightenment, which put an end to the Dark Ages, are ascribed to the invention of movable type by Gutenberg, or somebody else, at the end of the fourteenth century But the credit belongs rather to the unknown chemist who invented the process of making paper The ancient Romans stamped their bricks and lead pipes with type, but printing had to wait more than a thousand years for a supply of paper. Movable type is not the essential feature of printing, for most of the printing done now a days is not from movable type, but from solid lines or pages We could if necessary do away with type and press altogether, and use some photographic method of composition and reproduction, but we could not do without paper The invention of wood pulp paper has done more for the expansion of literature than did the invention of rag paper 600 years ago

Print is only an imperfect representation of the sound of speech, a particularly imperfect representation in the case of English because we can not tell how half the words sound from their spelling But the phonograph gives us sounds directly, and the audion and the radio have extended the range of a speaker, until now a speaker may have an audi-

World Wide Photos

OFFICERS OF THE *QUEST*

After the death of Sir Ernest Shackelton, Commander Frank Wild succeeded him as leader of the expedition. He is shown second from the left. In the center is Commander Wilson. Mr. Wilding is shown on the right with the camera.

ence covering a continent and including generations yet unborn What these inventions do for sound, photography has done for the sister sense of light By means of them man is able to transcend the limitations of time and space He can make himself seen and heard all round the earth and to all future years

SCIENTIFIC ITEMS

WE record with regret the death of Alexander Smith, formerly professor of chemistry at the University of Chicago and Columbia University; of Alice Robertson, formerly professor of zoology in Wellesley College; of David Sharp, formerly curator of the Museum of Zoology of the University of Cambridge and editor of the *Zoological Record*, of F. T Trouton, emeritus professor of physics in the University of London, and of E Bergmann, director of the Chemisch-Technische Reichsanstalt, Berlin

SIR ERNEST RUTHERFORD, Cavendish professor of physics at the University of Cambridge, has been elected president of the British Association for the Advancement of Science in succession to Sir Charles S. Sherrington. The meeting next year will be at Liverpool; the following year the meeting will be in Toronto.

DR ROBERT A MILLIKAN, chairman of the board of the California Institute of Technology and director of the Norman Bridge laboratory of physics, has been appointed a member of the committee on intellectual cooperation of the League of Nations to succeed Dr. George E. Hale, director of the Mt. Wilson Observatory, who has resigned from the committee owing to the state of his health.

PROFESSOR W. L. BRAGG, of Manchester University, who, together with his father, Sir William Bragg, was awarded the Nobel Prize for physics in 1915, delivered on September 6 the lecture in Stockholm as prescribed by the statutes of the Nobel Institution.

THIS year's Silliman Memorial Lectures at Yale University will be delivered by Dr. August Krogh, professor of zoophysiology in Copenhagen University. Professor Krogh has taken for his general topic "The Anatomy and Physiology of Capillaries."

THE SCIENTIFIC MONTHLY

DECEMBER, 1922

THE VEGETATION OF AUSTRALIA AND NEW ZEALAND

By Professor D. H. CAMPBELL

STANFORD UNIVERSITY

THOSE parts of the world which for one reason or another are completely isolated show very plainly the effects of this isolation upon the animals and plants which inhabit them. The degree of specialization in these organisms is to a certain extent an index of the length of time the region has been shut off. A comparison of these organisms with those of other regions may throw light upon such problems as the changes in the distribution of land and water upon the earth's surface in the course of ages, and thus be of great interest to the geologist and geographer as well as to the biologist.

If we compare the lands of the northern hemisphere, as they now exist, with the principal land masses of the southern hemisphere, we find the former to be very much more extensive than the latter. In the north there is a marked preponderance of land in the polar and subpolar regions, which merge into the temperate regions in both the American and Eurasian continents. In the southern hemisphere there is an extensive almost absolutely barren polar continent, but the regions corresponding to the subarctic land masses of the north are entirely occupied by water; and the south temperate regions are completely separated from the antarctic continent by a wide stretch of sea.

Moreover, the temperate regions of Australasia, South Africa and South America are widely separated from each other by the Atlantic, Pacific and Indian oceans. In extent the temperate regions of the south are much less than those of the northern hemisphere. As might be expected, this condition of things is accompanied by a much greater diversity in the temperate floras of the southern hemisphere than is the case in northern latitudes. This perhaps reaches its maximum in the Australasian region, the completely isolated Australian continent and the islands of New Zea-

land having extremely specialized floras which are of very great interest to the student of plant geography.

While Australia and New Zealand are usually grouped together geographically as "Australasia," they differ much from each other in their vegetation, although having more or less in common. New Zealand is separated from Australia by over a thousand miles of sea, and many of the most characteristic Australian types are quite absent, and others only very sparingly represented. Owing to its very much greater size and range of climate, Australia, as might be expected, possesses a much more extensive flora than the relatively small islands of New Zealand.

The completely isolated continent of Australia is almost exactly the size of the continental United States exclusive of Alaska. The Australian climate, however, is very different. The northern portion of Australia is within the tropics, the tip of York Peninsula being only 11 degrees from the equator, while the southernmost part of the continent scarcely touches the fortieth degree of latitude. The adjacent island of Tasmania extends about three degrees further south. The climate is therefore much warmer on the whole than that of the United States or Europe, the coolest regions in the south having a climate comparable to that of California or the Mediterranean. At the north a true tropical climate prevails.

The topography of Australia is much less varied than that of the United States. There are no mountains comparable to our great western ranges, and there is a marked dearth of large rivers and lakes. The principal mountain masses are close to the eastern coast, a succession of mountain ranges and highlands extending from the York Peninsula to eastern Victoria and Tasmania. In Queensland there are some definite mountain ranges, but for the most part the high land is a plateau sloping gradually westward, with more or less definite escarpments toward the east. These escarpments sometimes exhibit abrupt gorges cut by the streams. These are well shown in the Blue Mountains west of Sydney. The highest point in Australia is Mt. Kosciusko, 7,300 feet, situated in New South Wales near the Victoria border.

This highland region and the adjacent coastal areas have for the most part a good rainfall, but there are no large rivers. The heaviest rainfall is in the coastal region of North Queensland where at certain stations it may exceed two hundred inches annually and averages one hundred and fifty.

Inland, however, the rainfall diminishes rapidly, and a third of the continent is said to have ten inches or less annually and another third less than twenty. This means that two thirds of the area of Australia must be classed as desert or semiarid, and

much of it unsuited to agriculture, although vast areas are more or less adapted to grazing, which at present in much of the commonwealth is the most important industry. There is a more or less marked wet and dry season in most of Australia, as on our own Pacific coast. In the south most of the rain falls during the winter months, May to September; in the north the heaviest rains fall in the summer. June is the wettest month in the south, January in the north.

Northern Australia, lying entirely within the tropics, has for the most part a genuinely tropical climate, hot and humid in the coastal districts. In the more elevated regions of the plateau, however, there may be sharp frost during the winter months, June to August. In August of last year I observed bananas and other tender plants cut down by frost at an elevation of 2,000 to 3,000 feet, in latitude 17°. On the coast, however, frost is quite unknown, and the forest shows a genuine tropical luxuriance.

The wettest region in Australia is in northeast Queensland, on the coast, about latitude 17°. In this region a short range of precipitous mountains rises directly from the coast to a height of over 5,000 feet, the highest land in the state. At the foot of this range, the precipitation is very heavy. One place, Babinda, which I visited in August, 1921, had already registered over two hundred inches for the year, and it rained almost incessantly during my stay.

The low swampy forest about Babinda was almost impenetrable, the trees loaded down with creepers of various kinds, among which the rattan palms were only too conspicuous. Throughout the eastern tropics the thickets of rattans are a great hindrance to progress in the forest, as their tough, horribly spiny twining stems make absolutely impenetrable tangles, natural barbed-wire barriers. Climbing Aroids and species of Vitis and Piper are also abundant as well as various other lianas.

In these wet lowland jungles, the palms reach their fullest development, forming a conspicuous and beautiful feature of the vegetation. One of the commonest and most attractive species is *Archontophoenix Cunninghamiana*, often cultivated under the name *Seaforthia elegans*, and one of the most beautiful of all palms, with its smooth slender trunk and crown of graceful feathery leaves. No feature of the Australian vegetation is more beautiful than the groves of these lovely palms.

Screw-pines (Pandanus) abound in this region and there are also a number of species of Cycads. Australia is especially rich in these ancient plants. The most widespread genus is Macrozamia, of which there are several species, the genus having representatives in all the states. The two other Australian genera, Cycas and

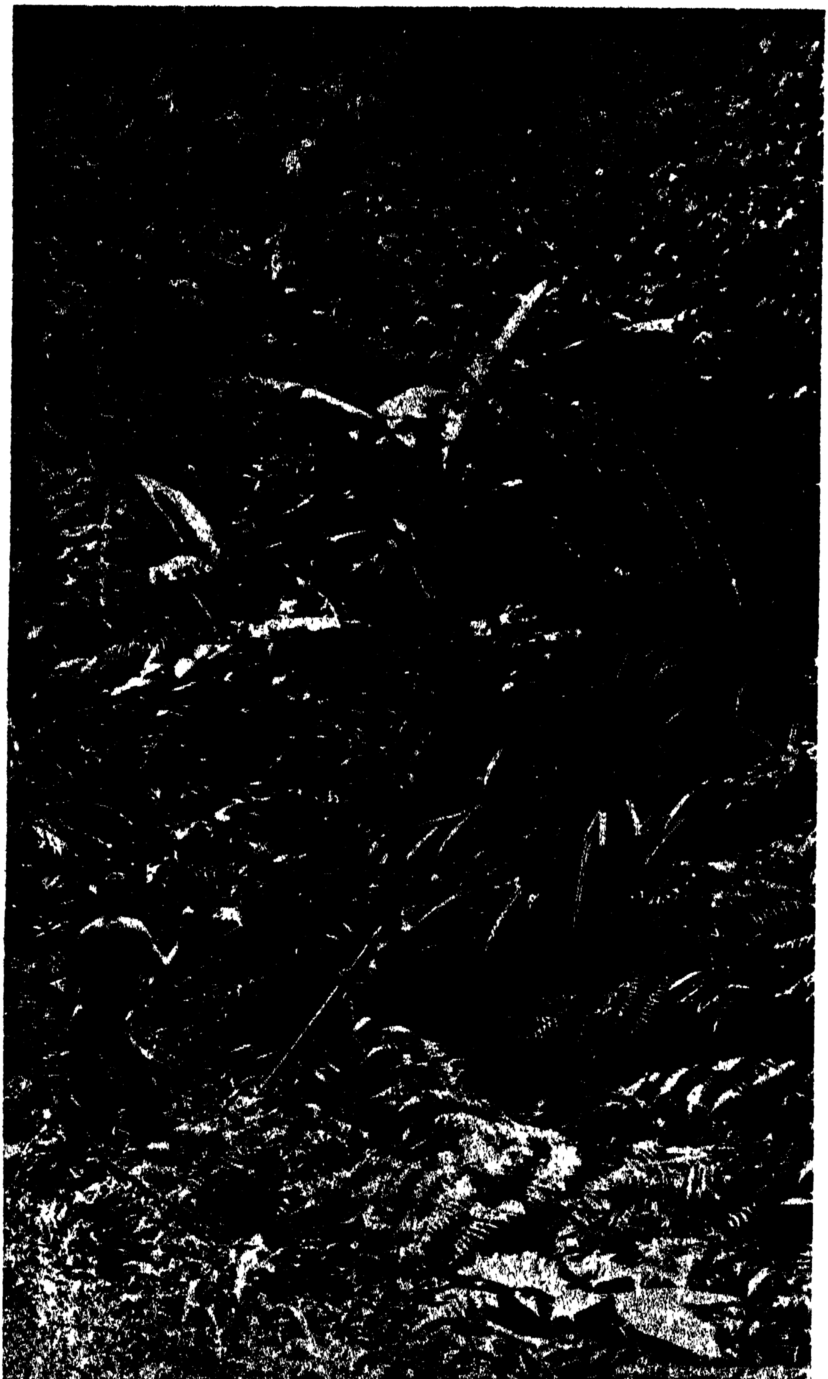


FIG. 1. TROPICAL RAIN-FOREST, NORTH QUEENSLAND

Bowenia, are confined to tropical Queensland. The latter genus, peculiar to Australia, differs much in appearance from any living Cycads, in its solitary bi-pinnate leaves, rather suggesting a bracken fern.

In the dryer parts of the Queensland coast the rain-forest is replaced by a more or less mixed forest, composed in part of Eucalyptus, and in part of tropical rain-forest types, like Ficus. A forest of this type may be seen occupying the sandy soil in the neighborhood of Cairns, the principal port of North Queensland.

A feature of the coast in this district is the mangrove formation along the shore and the banks of the streams flowing into the sea. Several genera are represented, the most important being the wide-spread Rhizophora and Avicennia.

Some interesting ferns were noted in this region, the most striking being a gigantic Angiopteris which was seen in several places in the vicinity of Babinda.

Immediately back of the coast the land rises rapidly to a plateau reaching an extreme elevation of about 4,000 feet, but averaging 2,000 to 3,000 feet over most of its extent.

This table-land has an ample rainfall, and on the better soils develops a fine forest which yields extremely valuable timber. Much of the timber has been destroyed, but there are still some remnants which are accessible, and these are really magnificent examples of tropical forest growth. This tropical rain-forest is known in Queensland by the very inappropriate name of "Scrub" and is confined to the rich basaltic and alluvial soils.

The trees of this forest are mainly of Malayan affinity, and are tall with lofty straight trunks yielding a large amount of fine timber. Some of them, especially the Kauri (*Agathis Palmerstoni*) and "Red Cedar" (*Cedrela toona*) reach a very large size. The latter was formerly abundant and sometimes attained a diameter of upwards of ten feet. It has been largely exterminated, but an occasional fine specimen may still be seen, and the same is true of the Kauri.

Belonging to the same family (Meliaceae) as the cedar are several species of Flindersia, which are locally known as "hickory," "maple," "beech," and other woods not in the least related to them. Other characteristic trees are Elaeocarpus, (Tiliaceae), *Aleurites Moluccana*, widespread throughout Polynesia; Sideroxylon (Sapotaceae), Eugenia (Myrtaceae) and others. The characteristic Australian family Proteaceae is represented in the rain-forest by several species of Grevillea, Stenocarpus, Macadamia and other genera. *Grevillea robusta* of southern Queensland is often grown in California as an ornamental tree.

This upland forest has much finer trees than the lowland forest

FIG. 2. TRUNK OF GIANT FIG, NEAR YUNGABURRA, NORTH QUEENSLAND

near the coast, but the palms and some other tropical types are almost entirely absent, and the development of the epiphytes and lianas is not so marked, although these are by no means absent. Many of the large trees, as is so common in rain-forests everywhere, show a conspicuous development of buttresses at the base of the trunk.

The giants of the forest are species of Ficus, the size of which is amazing. As in most tropical lands the genus is well represented in northern Australia, some species extending as far south as Sydney. Like so many other species of Ficus, these giant Queensland figs begin life as epiphytes, the descending roots finally coalescing more or less completely, and strangling the host tree. The descending roots are produced in great numbers and in one tree that was seen, the huge conical trunk formed by the united roots was said to measure 120 feet in circumference at the ground, and the enormous spreading crown was in proportion.

While the predominant forest on the plateau is "scrub," there are large areas occupied almost exclusively by open Eucalyptus forest. This Eucalyptus forest is the dominant type of vegetation over much of Australia, but in the region in question is restricted to areas of sandy soil. The line between the "scrub" and the Eucalyptus forest is often very sharply marked, and is probably determined by the difference in the soil.

In southern Queensland, in the neighborhood of Brisbane, the Eucalyptus forest predominates, though there are also areas occupied by "scrub," but many of the strictly tropical species of North Queensland are absent.

Probably the most striking tree of South Queensland is the "Bunya" (*Araucaria Bidwilli*) a coniferous tree confined to a relatively small area in this region. It reaches a large size, and is valuable for its timber. The big seeds were much prized as food by the aboriginals. This handsome tree is frequently cultivated in California, where it seems very much at home. A second species, *A. Cunninghamii,* is much more widely diffused, and was seen in extensive pure stands on some of the islands off the coast of Queensland.

An analysis of the constituents of the scrub vegetation of Queensland and New South Wales shows that it is largely made up of genera widespread through the Indo-Malayan region, or closely related to these, and may very properly be considered a part of the great Malayan flora. Such types as the figs, palms, screw-pines, Araceae, many epiphytic ferns and orchids are characteristic of the whole Indo-Malayan region; and as it is evident that northeast Australia was connected at no very distant period with the great island of New Guinea, it is pretty certain that this portion of the Australian flora is derived from the north.

FIG 3. BUNYA PINES (ARAUCARIA BIDWILLI), BOTANICAL GARDENS, BRISBANE

This Malayan flora is best developed in northeast Queensland, some of the forms like the pitcher plants (Nepenthes) and certain genera of palms (Borassus, Areca, Caryota, etc.) being confined to the York Peninsula, Australia's northernmost extension, which is separated from New Guinea by only about 100 miles of water.

Some of the Malayan types, like Cedrela and two or three palms, and a considerable number of others, extend southward to the borders of Victoria; but this vegetation is confined to regions of ample rainfall and rich soils, and the number of these Malayan types diminishes rapidly toward the south.

While the scrub vegetation is made up for the most part of the Malayan types there are a number of genera probably of Australian origin. Such are the fine trees Tristanea (allied to Eucalyptus) the silky oak (*Grevillea robusta*), Stenocarpus and Macadamia of the Proteaceae, a family which reaches its maximum development in Australia.

The luxuriant scrub-forest disappears as one proceeds inland, and with the diminishing precipitation is replaced by the open Eucalyptus forest. Still further inland in Queensland are extensive open grass lands or prairies which afford pasturage to great herds of cattle.[1]

To the south of Queensland is the state of New South Wales, the first colony to be established in Australia. The coastal region is a continuation of that of southern Queensland and has much the same vegetation as the latter, but the Malayan elements diminish toward the south, where there is an increasing proportion of true Australian types such as Eucalyptus and Acacia. The scrub, however, retains a decidedly tropical aspect, with tall palms and tree-ferns in abundance.

Much the greater part of the state, however, is far too dry for such forest growth, and is occupied by a very different type of vegetation. This is almost purely of Australian origin and is more or less decidedly xerophytic in character. The predominant trees are various species of Eucalyptus forming open forests with the sandy soil between occupied by a great variety of low shrubs, often with extremely showy flowers. Herbaceous plants are less conspicuous, although there are coarse grasses and a good many perennial plants growing from tubers, corms or bulbs. The Myrtaceae, so abundant in Australia, have numerous species of Leptospermum and Melaleuca; the Leguminosae include many species of Acacias, "Wattle" in the vernacular, and a bewildering array of showy Papilionaceae; several beautiful species of Boronia

[1] Maiden, J. H.: "Australian Vegetation," p. 207. *Federal Handbook for Australia*, Melbourne, 1914.

FIG 'ANICAL 'YDNEY

and Eriostemon (Rutaceae) and many other striking and unfamiliar flowers abound. The Proteaceae, as everywhere in Australia, are much in evidence, the most abundant being species of Hakea, Banksia and Grevillea. To this family belongs one of the most gorgeous of Australian flowers, the "Waratah," whose magnificent scarlet flowers are the pride of New South Wales. Another very striking plant peculiar to New South Wales may be mentioned—the giant torch lily (*Doryanthes excelsa*), bearing an enormous cluster of great scarlet lilies on a stout stalk ten or fifteen feet in height.

Victoria, the smallest state, occupies the southeast corner of Australia, and is about the size of Kansas. It is the best cultivated, and apparently the most prosperous state of the commonwealth. Much of the state has a climate adapted to the cultivation of most crops of the north temperate zone, and better suited to the North European settlers than the hotter parts of Australia. Its smaller size and more uniform rainfall result in a lesser variety of vegetation than in the larger states; but in the mountain districts of the east are found the tallest trees in Australia, close rivals of the California redwood. These forests of giant gums with their heavy undergrowth of tree-ferns and other luxuriant vegetation are among the finest in the world. Where the forest has been cleared, the land is some of the best in the commonwealth.

The distinctive Australian flora is seen at its best in West Australia. This immense state occupies the entire western third of the continent, and is almost completely separated from the eastern states by extensive deserts, and is itself very largely a region of extremely low rainfall. There is, however, a small region occupying the extreme southwest portion, which has a fairly heavy rainfall, and this district possesses a flora which for variety and beauty has scarcely a rival anywhere in the world.

Travelling overland from Victoria one traverses the rather uninteresting state of South Australia, and then proceeds by the recently completed line over the desert to West Australia.

This desert is not unlike certain parts of our own western arid regions, often suggesting parts of Nevada or Arizona. While extensive tracts show only sparse salt-bush (Atriplex, Kochia), much resembling the sage-brush deserts of Nevada or Utah, more often there is a fairly heavy growth of small trees, interspersed with low shrubs, and sometimes bunch grasses and a few flowering herbaceous plants.

The commonest trees are, as usual, species of Eucalyptus, but other abundant trees are species of Casuarina, whose thin leafless twigs simulate the needles of a pine. These curious trees, while not exclusively Australian, being also found in the Malayan region, reach their maximum development in Australia.

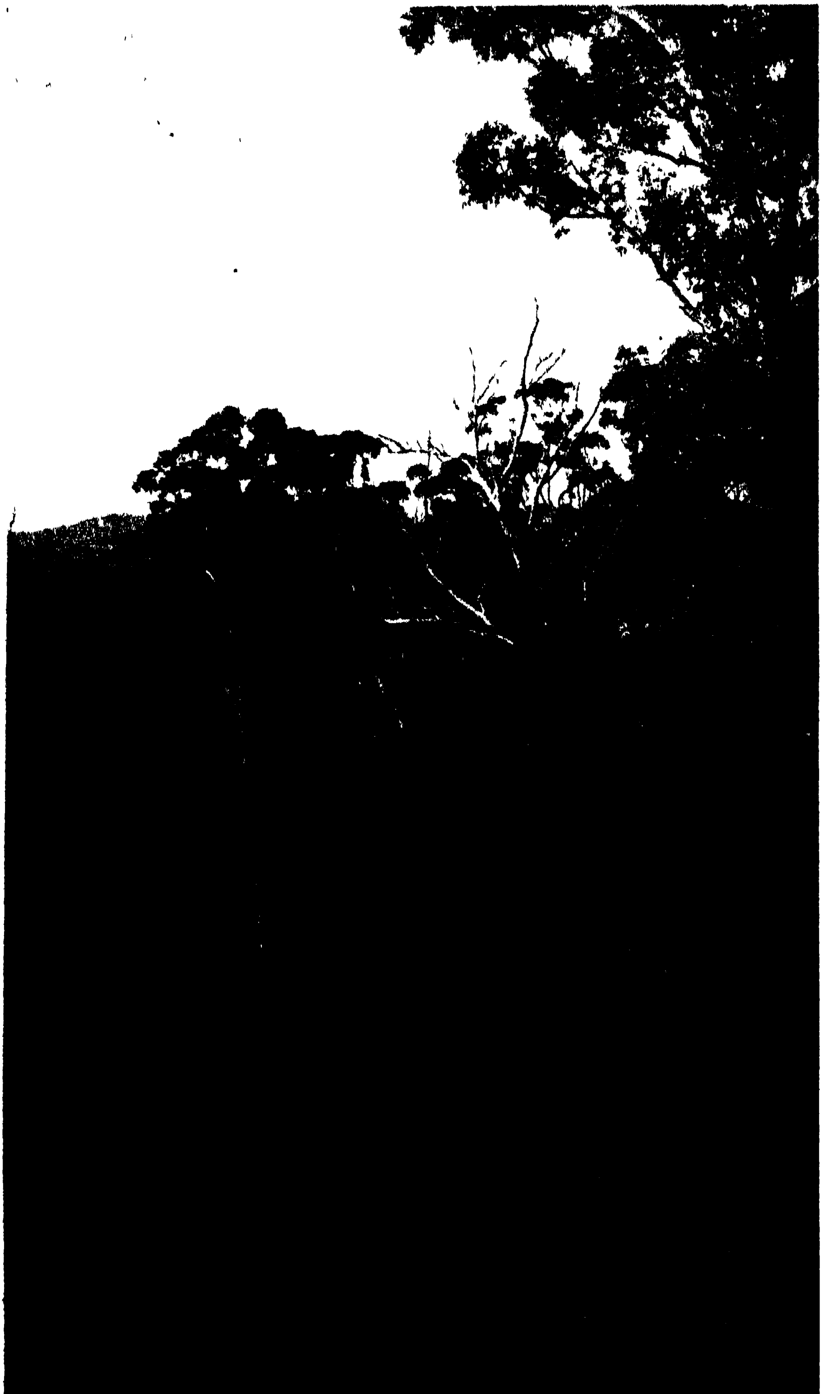


FIG. 5. GIANT GUM-FOREST, VICTORIA

The commonest shrubs are species of Acacia and dwarf Eucalyptus, the former at the time of my visit being covered with masses of golden bloom, which enlivened the prevailing dull gray green tints of the foliage. A species of sandal-wood grows in this region as well as a number of other interesting trees and shrubs.

Comparatively few showy flowers are seen, aside from the Acacias. Occasionally masses of pretty pink and white everlastings are encountered, and a gorgeous scarlet pea (*Clianthus Dampieri*).

As the western coast is approached the country becomes somewhat less arid, and presently there appears along the railway line an increasing profusion of beautiful flowers, until before Perth, the terminus of the railway, is reached, the train travels through a veritable garden of brilliant bloom. The beauty and variety of this wonderful floral display must be seen to be appreciated. While some of the flowers, such as the great variety of pea-shaped blossoms, suggest familiar northern types, many are entirely strange with little suggestion of relationship with any northern genera.

Whole families, quite unknown to this northern botanist, are richly represented. Thus the Goodeniaceae, a characteristic Australian family, has a large number of extremely showy species of Goodenia (yellow), Dampiera and Leschenaultia (blue), one of the latter, *L. formosa,* of a wonderful blue that would put to shame an Alpine gentian.

Ground orchids are very abundant, some of them of great beauty. They belong largely to special Australasian genera, Caladenia, Diuris, Thelymitra and other quite unfamiliar ones. The little sundews of northern bogs are here represented by an extraordinary assemblage of species, some slender, half climbing plants four to five feet high with flowers the size of small roses. Pink Boronias and Tetratheca (Tremandraceae), yellow Hibberties (Dilleniaceae) are a few of the many beautiful novelties among the lower growing species; while Banksias, Hakeas and Grevilleas of the Proteaceae; Leptospermum, Callistemon, and Melaleuca of the Myrtaceae, are the predominant larger growths.

Of the Monocotyledons, aside from the orchids already referred to, and various grasses and sedges, there are a number of attractive species. The Iridaceae are represented by species of Patersonia with pretty blue or purple flowers. Of the lily-family are several species of Thysonotus, with delicate fringed petals, and Burchardia, whose umbels of pretty white blossoms suggest an Allium or the Californian Brodiæa.

Peculiar, if not beautiful, were the extraordinary grass-trees, or "black-boys," as they are commonly called in the West. The larger species develop a stout trunk and somewhat resemble an

Photograph furnished by Mr. C. E. Lane-Poole.

FIG. 6. GRASS-TREES (XANTHORRHŒA PREISSII), WEST AUSTRALIA

arborescent Yucca, but the leaves, which are very numerous, are slender and more or less drooping. The insignificant flowers are borne on a club-like spike, sometimes six or eight feet high. The plants are said to flower especially freely after a recent fire, and a grove of these strange plants with hundreds of these upright flower-spikes is one of the most striking botanical sights of Australia. A related genus, Kingia, is confined to western Australia.

Among the most extraordinary flowers of West Australia are the "Kangaroo Paws" (Anigozanthus). These flowers are of the most bizarre coloring—bright green and scarlet, yellow and black, red and yellow, or pure green. The genus is unknown outside West Australia. The only Gymnosperm noted was a Cycad, *Macrozamia Fraseri*. This is very common, and is regarded as a serious pest, as animals are often poisoned by eating the young foliage in time of drought. Throughout the less arid parts of West Australia, this wonderful floral display may be seen in the spring, August to November. It perhaps reaches its culmination in the Albany district on the south coast. Certainly the variety of flowers near Albany surpasses anything the writer has seen in any part of the world.

I was unable to visit the Island of Tasmania, which differs much in its topography and climate from the mainland of Australia, and is much more like New Zealand in these respects. It is very mountainous and in many parts, especially in the west, the rainfall is extremely heavy. This heavy precipitation and relatively low temperature resemble the climatic conditions in the south island of New Zealand, and there is a considerable degree of resemblance in the vegetation of the two regions.

In common with New Zealand there is an important element of the flora closely related to, or even identical with, South American species. Some of these "Fuegian" plants are found also in the parts of the adjacent state of Victoria and also as Alpines in the mountains further north.

The most striking of these are the evergreen beeches (*Nothofagus spp.*) which are a notable constituent of the flora of southern Chile and also of New Zealand. These are the sole representatives of the Cupuliferae (oaks, beeches, etc.) found in Australasia.

The visitor to Australia is immediately impressed by the predominance of the Eucalyptus forest, and indeed this is the commonest tree genus. While much of this open forest is extremely monotonous and unattractive, it must be remembered that among the more than two hundred species there are some of the stateliest and most beautiful trees known anywhere. The great Karri forests of West Australia and the giant gum forests of Victoria, as well as some of the Eucalypts from the rich mountain forests

of New South Wales and Queensland, are some of the most magnificent the writer has ever seen.

In the spring, when the new foliage is developing, many species show beautiful golden and ruddy tints in the young leaves that are in strong contrast with the gray-green of the adult foliage of most species. In the arid regions of the interior there are dwarf species shrubs of moderate size remarkably resistant to drought.

The flowers of some species of Eucalyptus are very beautiful and produced in great profusion. As in so many Myrtaceae the numerous stamens form the showy part of the flower and are pure white, pink or scarlet in color. The splendid *E. ficifolia* with brilliant scarlet stamens is a favorite ornamental tree in parts of California.

The Myrtaceae, aside from Eucalyptus, are very largely developed in Australia, being second in number of species in the Australian flora,[2] more than eight hundred having been described. Allied to Eucalyptus are Tristanea, Angophora and Syncarpia, all fine trees of large size.

In the moister and warmer areas of the coast are members of the widespread genera Myrtus, Eugenia and Barringtonia, the latter entirely tropical in its habitat, a very beautiful tree with large glossy leaves and big white flowers. The genus is common throughout the Malayan region and the southern islands of Polynesia.

More characteristically Australian and represented by many species are the genera Leptospermum and Melaleuca, very widely distributed and often forming extensive thickets. Some of the Melaleucas are small trees; the Leptospermums are as a rule shrubs of medium size. The flowers are usually white and produced in great profusion, so that some species are very attractive when in flower and prized as garden ornaments. Other characteristic Myrtaceae are the showy red "bottle-brushes"—species of Callistemon and the pretty fringed flowers of the West Australian Verticordias.

First in number of species in the Australian flora is the great family of Leguminosae, with over one thousand species. Acacia leads with upwards of four hundred, ranging from tiny shrubs a few inches in height to large trees. The Acacias are popularly known as "wattle," and in the spring the profusion of golden bloom of many species makes them very conspicuous. Some of these Australian wattles are common in cultivation and often called "Mimosa." The majority of the Australian Acacias are of the "phyllodineous" type, *i. e.*, the feathery leaf-lamina is sup-

[2] Maiden, *loc. cit.*, p. 166.

pressed and the flattened leaf-stalk, or "phyllode," looks like a simple lanceolate leaf.

The section Papilionaceae, or Pea family, contributes a host of showy flowers to the floral show. Nearly all of these exhibit very brilliant colors, pink, crimson, scarlet, orange, yellow, blue and purple, and the flowers are borne in profusion. Many belong to strictly Australian genera—*e. g.*, Chorizema, Gastrolobium, Jacksonia, etc., and comparatively few are in cultivation.

The third family, in point of numbers, the Proteaceae, has not a single representative in the United States, and is almost entirely absent from the northern hemisphere. About two thirds of the species belong in Australia, and South Africa is next in number of species. The Proteaceae are mostly shrubs of moderate size, but a considerable number are arborescent, becoming forest trees. Of these trees, the most important are the species of Grevillea Banksia, Stenocarpus, Macadamia and several others peculiar to the rain-forests of Queensland. The handsome *Grevillea robusta* is a fine tree frequently seen in California, and a few other species of Grevillea and Hakea are less commonly seen in gardens; but many fine species, well worth cultivation, are still to be seen only in the wild. Grevillea is the largest genus and is widespread in Australia. The flowers are often very showy, pink, scarlet or yellow. Hakea, next in number of species, has as a rule rather inconspicuous flowers.

Few Australian trees are more peculiar in habit than some of the Banksias, whose stiff serrate leaves and huge oblong heads of yellow flowers are most peculiar and striking. The great majority of the Proteaceae are xerophytic, but a few inhabit the scrubs of New South Wales and Queensland. Perhaps the finest flowers among the Proteaceae belong to the "Waratah" of New South Wales, previously referred to. Other important families, nearly or quite confined to Australia, are the Tremandraceae, Goodeniaceae, Candolleaceae and Casuarinaceae.

Reference has already been made to some of the Australian Gymnosperms, which are extremely interesting. The Cycads have already been mentioned, as well as the Araucarias and Kauri of Queensland. The coniferous types of the northern hemisphere are absent, the nearest relation being the genus Catlitris, which is related to the cypresses.

The Yew family or Taxaceae, however, is remarkably developed in the southern hemisphere and has a number of extremely interesting forms in Australia and especially Tasmania. Podocarpus, of which a small number of species occur in the warmer parts of the northern hemisphere, is the most important Australasian genus,

and comprises a number of large and valuable trees, as well as some smaller ones. Species occur in all the states.

Certain genera, absent from the mainland, are found in Tasmania and New Zealand. Such genera are Phyllocladus and Dacrydium, as well as several others.

Ferns and their relatives are scarce or entirely wanting in a very large part of Australia, owing to the prevalence of arid and semi-arid conditions unsuited to these moisture-loving plants. There are, however, regions where they abound and are an important feature of the vegetation. The ubiquitous bracken-fern (*Pteridium aquilinum*) often covers large tracts of open land, as in northern regions; and in the moist gullies of the Blue Mountains of New South Wales and the forests of Victoria or in the rain-forests of the north there is a rich assortment of Pteridophytes, including some very fine treeferns, interesting Lycopods and the curious Psilotum and Tmesipteris, whose life-histories, which long baffled the botanist, have at last been revealed through the labors of Lawson and Holloway.

In the rain-forests are many epiphytic species, of which the extraordinary stag-horn ferns (Platycerium) are the most conspicuous; but there are also a good many of the beautiful and delicate filmy ferns (Hymenophyllaceae).

New Zealand

New Zealand comprises two large islands of about equal size and several adjacent ones of very much smaller dimensions. The northernmost point of the North Island is about 34° south latitude, and the South Island extends to south latitude 47°. The total area of the islands is about 100,000 square miles.

New Zealand presents a marked contrast to Australia, both in its topography and climate. Its relatively small area results in a climate of distinctly insular character, with very much less range of temperature and precipitation than is the case in continental Australia. Owing to its higher latitude, the climate as a whole is rather cool, but severe cold is rare in the lowlands. It is comparable with the climate of Britain, but especially in the North Island is considerably warmer. Owing to the proximity of the sea, there is less difference between North and South than might be expected. Thus between Auckland in the North Island and Invercargill, about ten degrees further south, there is less than ten degrees difference in the average temperature.

For the most part rain is abundant and well distributed, and much of the country shows a luxuriant growth of forest. There are certain regions, however, notably the Canterbury Plain of the South Island, which have a relatively scanty rainfall and are

mostly destitute of trees. These grass-covered plains may be compared to the prairies of the mid-west of the United States.

The topography of New Zealand is for the most part exceedingly rugged, with much higher mountains than those of Australia. In the North Island are extensive volcanic formations, some of which are still active. In the Rotorua district, familiar to tourists, are numerous hot springs and geysers much like those of the Yellowstone and in addition there are active volcanic craters.

In the neighborhood of Auckland are a number of very perfect extinct cones, and on the west coast is Mt. Egmont, over eight thousand feet high. To the south lies the Wellington district, extremely rugged in character. The harbor of Wellington, surrounded by steep mountains, opens into Cook's Strait, separating the North and South Islands.

The South Island shows less extensive evidences of volcanic activity than the North Island. It is distinguished by the lofty snow-clad range of the Southern Alps near the west coast, culminating in the majestic Mount Cook, over twelve thousand feet high, snow covered for most of its height and with extensive glaciers reaching nearly to its base. The southwest coast is indented by numerous fiords, which are said to present a magnificent spectacle.

The Southern Alps exercise a great influence on the climate of the South Island, intercepting a very large part of the moisture from the seaward side. Between the mountains and the coast there are stations with as much as two hundred inches of rain annually, while Christchurch on the east coast has only about twenty-five inches, and there are a few stations with even a lighter precipitation. This dry region is mostly destitute of trees, the ground being covered with coarse tussock-grasses. The contrast between these dry grasslands and the densely forested regions of rainy Westland is most striking.

To the south of the great mountain range the conditions are more uniform, and the whole southern end of the South Island is covered with forest.

The North Island originally was almost completely covered with heavy forest, in which the most important tree was the Kauri pine (*Agathis australis*). Very little of this splendid forest remains, and the Kauri is almost extinct. A few small tracts have recently been reserved, and I had an opportunity of visiting one of these in the extreme northern part of the island. This new park is of limited extent, but is a typical example of the magnificent Kauri forest which once covered the desolated regions now occupying most of the surrounding country.

The Kauri is entirely different in appearance from any conif-

FIG. 7. KAURI FOREST, NORTH ISLAND, NEW ZEALAND

erous tree with which the American botanist is familiar. In its younger stages it shows the symmetrical pyramidal habit of most conifers, but the early branches finally fall off, leaving a perfectly smooth cylindrical bole with very little taper. This columnar trunk may reach a height of sixty to eighty feet, or even more, with a diameter of eight to ten feet, or it is said of twice this size. At the top there are several enormous diverging branches forming an immense spreading crown which overtops the other trees of the forest and gives the tree a most characteristic appearance.

The interior of the Kauri forest, with the huge smooth gray columnar trunks, is most impressive, and only rivalled by the great coniferous forests of the Pacific Coast, or the Cyptomerias of Japan. The New Zealand Kauri must rank as one of the giants of the vegetable kingdom.

Associated with the Kauri are a number of other trees, including several other Conifers or rather Taxads, as these belong to the Yew family. Of the latter the most important are the "Totara" (*Podocarpus Totara*) and "Rimu" (*Dacrydium cupressinum*), both valuable timber trees. The curious *Phyllocladus trichomi-noides* with flattened twigs (cladodes) looking like small fern-leaves, is not uncommon in this region. Some other characteristic trees are *Weinmannia sylvicola* (Saxifragaceae), said to be the commonest tree in New Zealand, and *Beilschmiedia tarare*, belonging to the Lauraceae.

A number of fine shrubs, *e. g.*, Coprosma, Pittosporum, Nothopanax and others are common, and as in all New Zealand forests ferns are much in evidence. The abundant and beautiful tree-ferns lend a special charm to the New Zealand forest. The finest of these is *Cyathea medullaris*, which may reach a height of upwards of fifty feet and is the finest tree-fern with which I am acquainted.

Other interesting ferns are several species of Gleichenia, and the climbing fern, *Lygodium articulatum*, which is said to climb to the top of lofty trees. Filmy ferns (Hymenophyllaceae) are common in the damp shady woods, but are hardly as abundant or luxuriant as in the rain-forests of the South Island.

Epiphytes abound in the rain-forests and include many conspicuous mosses and liverworts as well as ferns and various flowering plants. Among the latter are a number of orchids, but these are mostly inconspicuous species, far inferior in beauty to some of the fine Australian epiphytic orchids. Perhaps the most conspicuous epiphyte is a very common liliaceous plant, *Astelia solanderi*, forming great tufts of stiff sword-shaped leaves on the trunk or branches of many trees. It very often is seen on the slender stem of the Nikau palm, forming great bunches completely surround-

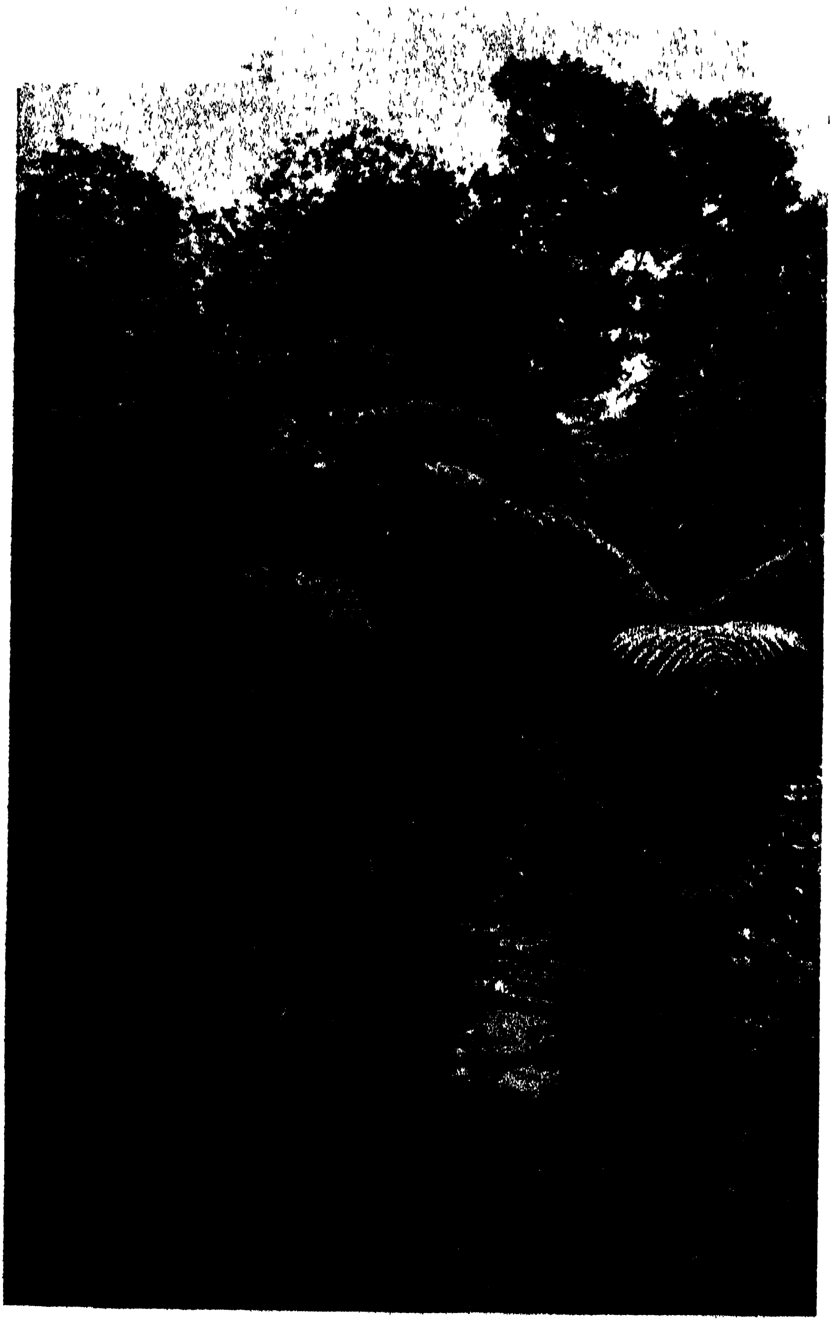


FIG. 8. TREEFERNS, NEW ZEALAND

ing the trunk. This palm (*Rhopalostylis sapida*), is the only palm native to New Zealand.

Where the land has been cleared it is often invaded by the ubiquitous bracken (*Pteridium aquilinum*), and another plant which quickly takes possession is the "Manuka" (*Leptospermum scoparium*), closely resembling some of the Australian species. When in bloom the shrub is decidedly ornamental, with myriads of pretty white flowers.

In open, more or less swampy districts, all over New Zealand, two extremely characteristic plants can hardly fail to attract attention. These are the native "flax" (*Phormium tenax*) and the "cabbage-tree" (*Cordyline australis*), often grown in California under the name Yucca-palm. The flax yields an abundant and valuable fibre, which is manufactured on an extensive scale and is one of the most important products of the country. At the time of my visit both of these striking plants were in flower. The flax sends up from its tuft of broad leaves, five or six feet high, scapes about twice as tall, bearing racemes of tubular red flowers which are much frequented by honey-sucking birds. The stately Yucca-like Cordylines bear immense panicles of small white fragrant flowers.

Among the most widespread trees of New Zealand are several species of Metrosideros, a genus occurring throughout Polynesia and Australasia. *M. robusta*, the "Rata," is a very beautiful tree with glossy green leaves and bright red flowers. Like Eucalyptus, to which it is not very distantly related, the bright-colored stamens are the showy part of the flower. Another species, *M. tomentosa*, also with showy flowers, is abundant about Auckland, and several other species, some of them climbers, occur in various parts of New Zealand. *M. robusta* begins life as an epiphyte, the trunk of the older tree being made up of the united descending roots, as is so often the case in many species of Ficus.

The southern portion of the North Island has a somewhat different vegetation from that of the Auckland district. The Kauri is quite absent from this region, and in some districts there are forests of evergreen beeches much like those of the South Island.

In the immediate vicinity of Wellington the forest shows many of the same trees as that further north, *e. g.*, Podocarpus, Dacrydium, Metrosideros, Weinmannia, Beilschmiedia and others. Among these is one of the two species of Proteaceae found in New Zealand. This is a handsome tree, *Knightia excelsa*, somewhat resembling the Australian Banksias.

One of the most interesting small trees is a Fuchsia, *F. excorticata*, New Zealand having three species of this otherwise exclusively South American and Mexican genus.

Photograph by Dr L. Cockayne.

FIG 9. CABBAGE-TREES (CORDYLINE AUSTRALIS) AND NEW ZEALAND FLAX (PHORMIUM TENAX)

Shrubby Compositae are common in New Zealand. The genus Olearia, much like Aster, is well represented, some species having fine flowers, others like *O. ilicifolia* with handsome evergreen foliage. Another peculiar genus is *Raoulia*, which includes the "vegetable sheep," *R. eximia.* Some other characteristic shrubs noted near Wellington are species of Melicytus, Elaeocarpus, Myrsine and Sophora. *S. tetraptera,* with brilliant yellow, very conspicuous flowers, is one of the few really showy New Zealand shrubs.

Wellington has an attractive if not large botanical garden of which the most interesting feature is a small ravine in which are growing many of the native trees and shrubs as well as some fine ferns and liverworts. Some of the treeferns are very tall and make a fine show. Of the liverworts the most notable is the remarkable *Monoclea Forsteri,* a giant among liverworts. This species is abundant about Wellington and also in various part of the South Island. The only other species known occurs in tropical America.

In the botanical gardens in Wellington are some fine exotic conifers, including a number of Californian species. One of these, the Monterey pine (*P. radiata*) is extensively planted in New Zea-

land, where it grows with extraordinary rapidity and furnishes a large amount of timber.

Across the harbor from Wellington at Day's Bay is a considerable extent of forest made up almost exclusively of two species of evergreen beeches (*Nothofagus fusca* and *N. Menziesii*). This forest is much more open than the mixed forest which prevails over most of the country near Wellington. These beeches, except for their much smaller leaves, are not unlike the true beeches of northern forests. They also remind one, in general habit, of the tree alders of the Pacific Coast.

Cook's Strait, separating the North and South Islands, does not seem to form an appreciable barrier to the migration of plants between the islands, there being little difference in the vegetation on the two sides of the Strait. Probably the separation of the two islands took place at a comparatively recent date, so that there has not been time for any marked change in the vegetation.

The important city of Christchurch is surrounded by the famous Canterbury Plain, an open grassland which like our western prairies is admirably adapted to agriculture.

The trip across the South Island from Christchurch to the west coast is full of interest to the botanist and includes some magnificent scenery. I had the good fortune to be accompanied by Dr. L. Cockayne, the well-known botanist, whose knowledge of the native flora is both extensive and accurate.[3]

The Canterbury Plain, where it has not been cultivated, is covered with tussocks of coarse grass, and this is true also of the lower slopes of the mountains on the eastern side. The most abundant species is *Festuca Novae Zealandeae*, but *Poa caespitosa* was another common and conspicuous species.

The change from this open grassland to the first beech forest is very abrupt, and marks the beginning of the western rainy district. The beech forest is very dense, and composed exclusively of the mountain beech (*Nothofagus Cliffortiana*).

At the summit of Arthur's Pass, about 3,000 feet elevation, the increasing moisture becomes more evident. The open stony ground supports a heavy growth of herbaceous plants and low shrubs. In this formation is found perhaps the most beautiful of all new Zealand flowers, *Ranunculus Lyallii.* This fine plant has very large undivided peltate leaves, and clusters of pure white flowers two inches or more in diameter, borne on stout stalks a foot or more in height. Another charming flower is *Ourisia macrocarpa,* with large flowers something like Mimulus.

[3] Dr. Cockayne's book, "New Zealand Plants and Their Story," Wellington, 1919, is an admirable account of New Zealand vegetation.

The sub-alpine scrub of this region is composed of a number of very characteristic species. The most casual observer cannot fail to note the Dracæna-like *Dracophyllum Traversii,* a small tree with clusters of reddish leaves at the tips of the straggling branches. In spite of its Yucca-like habit, this is a heath of the family Epacridaceae. Various shrubby Veronicas, a genus developed to a remarkable degree in New Zealand, are abundant and several shrubby Compositae (Olearia, Celmisia, Senecio) abound. A curious leafless leguminous shrub, *Carmichælia sp.,* is noted and a species of Gaultheria, and an Araliad (*Pseudopanax lineare*) are not uncommon. Along the roadside the mountain flax (*Phormium Colensoi*) is frequent. The descent on the west side, through the magnificent Otira Gorge, is one of the finest pieces of scenery in New Zealand. The very steep walls of the gorge are densely covered with luxuriant forest from crest to base.

The very heavy rainfall of this district is attested by the luxuriant rain-forest which reaches its maximum development on the west side of the range. At first there is some admixture of beech, but this finally disappears and in the typical Westland rain-forest is quite absent.

The banks along the roadside show a constantly increasing profusion of ferns, liverworts, and moisture-loving herbs, like violets, Hydrocotyle and the interesting Gunnera, a genus particularly developed in New Zealand.

Tree-ferns, which had not been seen at the higher elevations, increase in size and numbers as the lowlands are approached and in the lowland forest form a conspicuous and beautiful feature.

The Westland rain-forest is one of extraordinary luxuriance. The extremely heavy precipitation and mild temperature result in a rich profusion of vegetation that has all the aspects of a genuine Malayan rain-forest. Composed of exclusively evergreen trees and shrubs, draped with lianas and epiphytes and interspersed with thousands of noble tree-ferns, it was hard to believe that this forest was in latitude 43°, corresponding in the United States to the latitude of Buffalo.

This forest is of the type called "Taxad" by Cockayne, the most important trees belonging to the taxaceous genera Podocarpus and Dacrydium. In the swampy areas the "white-pine" *P. dacrydioides* predominates, a very tall tree with fine straight trunk yielding valuable timber. Of the angiospermous trees the most abundant is *Weinmannia sylvicola,* a tree of Malayan affinity, and its relative, *Quintinia acutifolia,* both belonging to the Saxifrage family. A very common large shrub is *Aristotelia racemosa,* with rather attractive pinkish flowers, and other common shrubs are species of Coprosma, *Metrosideras lucida,* and *Pseudopanax crassifolia.*

Ferns and other Pteridophytes abound in these wet forests. Various species of Lycopodium are abundant, and also the curious Tmesipteris. Of the tree-ferns, the commonest is *Dicksonia squarrosa*, sometimes twenty to thirty feet high. Less abundant is *Hemitelia Smithii*. Of the abundant epiphytic growths the most beautiful are the filmy ferns (Hymenophyllaceae) which in these Westland forests attain their finest development. Another extremely beautiful fern is *Todea* (*Leptopteris*) *superba*.

As might be expected, these supersaturated forests are a veritable garden of mosses and liverworts which drape the trees and form a thick carpet on the ground and big cushions over every prostrate log and stump. Great tussocks of Sphagnum are common about the pools, and now and then one encounters colonies of the giant *Dawsonia superba*, the last word in moss development. The abundance and luxuriance of the liverworts is astounding; indeed, it is doubtful if anywhere else in the world is a richer growth of these interesting plants to be found.

Of the lianas the most interesting is *Freycinetia Banksii*, a distinctly tropical genus belonging to the screw-pine family, abundant throughout Polynesia and the Malayan region.

Everywhere in the New Zealand rain-forests there is a rich development of epiphytes and climbing plants. Of the epiphytes there are two categories, those that begin life as epiphytes, but later become rooted in the ground, and those which retain permanently the epiphytic habit. Among the latter are many ferns, Lycopods, Mosses and liverworts, as well as a good many flowering plants like Peperomia, various orchids, Astelia, etc. Of the ferns the filmy ferns or Hymenophyllaceae are especially numerous and beautiful.

Several species of New Zealand trees begin life as epiphytes. The seeds germinate in the branches of some tree and presently the young plant sends out roots which descend the trunk of the host-tree until they reach the earth. In course of time these descending roots coalesce in a more or less solid trunk and the host-tree may be completely strangled in the process. The "rata" (*Metrosideros robusta*) is the best known of these temporary epiphytes. Others are *Dracophyllum arboreum* and *Griselinea littoralis*.

Some of the climbing plants are great woody lianas, whose stout cables are thrown from tree to tree. One of the biggest of these is a huge bramble, *Rubus australis*, whose stems, sometimes six inches in diameter at the base, reach the tops of the tallest trees. Freycinitia climbs by means of roots, clinging to the trunks of trees, and some species of Metrosideros have a similar habit. Other common climbing plants are species of Clematis, Par-

sonsia and Mühlenbeckia and the climbing fern *Lygodium articulatum.*

Compared with Australia there is a remarkable scarcity of brilliantly colored flowers, a large proportion of the plants having white or greenish flowers. The bright red flowers of some species of Metrosideros, *Clianthus puniceus* and the native flax, bright yellow of *Sophora tetraptera,* the blue of many Veronicas and the blue or purple of some of the Compositae are the most marked exceptions to the rule.

Weeds

As in all countries where the white man has settled there have come with him many plant immigrants, some of which are not entirely welcome. These weeds hail from many lands. In the hotter and dryer parts of Australia they may come from such tropical countries as India, Brazil or Africa, while in the more temperate regions of southern Australia and New Zealand they are largely from northern Europe and America, *e. g.,* thistles, sorrel, dock, plantain and other familiar weeds.

Parts of Australia have been invaded by species of prickly pear (Opuntia) from America, which are a very serious pest. It has been said that in Queensland 30,000,000 acres of land have been invaded by one species which has caused immense damage.

From America have also come species of cockle-bur (Xanthium) and Stramonium, as well as several other pestilent weeds. In the moister cooler regions of Australia and New Zealand, the common European blackberry, sweet brier and gorse have escaped from cultivation and become very persistent and troublesome weeds.

A number of plants from the Cape, whose climate is very similar to that of Australia, have become completely naturalized. It is not uncommon to see the familiar calla growing in ditches and low ground, and several of the beautiful Iridaceae from South Africa—Ixia, Sparaxis, Watsonia and Homeria—very often are seen growing along the railway embankments. The latter is said to be poisonous and may perhaps be called a weed. This name may also be given to the "Cape-weed" (*Cryptostemma calendulacea*), a daisy-like Composite which is extremely abundant.

Conclusion

Attention has already been called to the evident close relationships existing between the Australian "scrub" floras and those of the Indo-Malayan regions. The rain-forests of Queensland and New South Wales may be looked upon, with little question, as the remnants of a much more extensive flora which occupied these regions when they were united with New Guinea and separated

from the ancient Western Australian continent. It is generally believed that in the latter, which was probably much larger than at present, the ancestors of the characteristic types which now dominate the flora of the greater part of modern Australia had their origin.

In the old Western continent, completely isolated from other lands, there was an extraordinary development of a comparatively small number of families. The most conspicuous examples of this are the Myrtaceae, with over 200 species in Eucalyptus alone; Leguminosae, especially Acacia with over 400 species, and many peculiar Papilionaceae; Proteaceae with over 600 species (Grevillea, Hakea, Banksia, etc.). A few families, *e. g.*, Candolleaceae, Goodeniaceae, are almost exclusively Australian and especially abundant in Western Australia.

These peculiar Australian plants are largely xerophytic, and after the union of Eastern and Western Australia it may be assumed that the extreme aridity and poor soils of much of the central part of the continent would be much more favorable to these Western xerophytes than to the Malayan types of the East which have evidently been largely evicted by the drought-resistant West Australian immigrants, and are now restricted to comparatively limited areas where there is good soil and abundant moisture.

The autochthonous types have for the most part remained in Australia. Eucalyptus, Acacia, a few Proteaceae and some others are represented in the savannahs of Southern New Guinea and the dryer portions of the Malay Archipelago; and a few genera range through Polynesia; but the great majority of the true Australian species are unknown outside the Australian continent.

In the southeast, and especially in Tasmania, there is a marked infusion of plants whose relationships are with the Andean and Fuegian vegetation of South America. Most of these occur also in New Zealand.

Comparing New Zealand with Australia, there is found a good deal in common in the floras of the northern districts, *i. e.*, the Malayan rain-forest vegetation. This type is, however, of very much greater importance in New Zealand, where in spite of a much cooler climate, a large proportion of the trees and shrubs are more or less closely related to Malayan ones.

There is strong evidence of former connections with the tropical regions to the North, and it is quite as likely that the Malayan genera which New Zealand shares with Australia have been derived from the North and not directly from Australia.

The distinctively Australian genera are relatively few in New Zealand, and a striking feature of the flora is the absence of such

predominant Australian genera as Eucalyptus and Acacia. The family Myrtaceae, with over 800 species in Australia, has barely twenty in New Zealand, only one genus, Leptospermum, being typically Australasian. The Proteaceae, which reach their maximum in Australia, with more than 650 species, have only two representatives in New Zealand. There are, however, a considerable number of Epacridaceae, and several Australian genera of orchids, as well as Compositae and Leguminosae. It has been suggested, however, that some of these forms might be of New Zealand origin and migrants into Australia.

Most of the ferns common to the two countries are widespread Australian-Malayan species, but mention should be made of one, *viz.*, *Todea barbara*, common to northern New Zealand and New South Wales and also found in South Africa.

The Fuegian genera already referred to are mostly shared by Australia and New Zealand. Of these there are twenty-two genera common to the two countries, among which may be mentioned Astelia, Muehlenbeckia, Drimys, Nertera and the evergreen beeches, Nothofagus.[4]

There are sufficient resemblances between the floras of Australia and South Africa to indicate some former land connections between the two, but it is probable that the connection was severed at a very remote period.

In South Africa, as in Australia, there is a remarkable development of Proteaceae, but there are no genera common to the two, indicating a very long period of separation. The true heaths (Ericaceae) which are a marked feature of the South African flora are replaced in Australia by the Epacridaceae. It has been suggested[5] that the two families are offshoots of a common stock, differentiated since the disappearance of a former land connection.

It is pretty well agreed that at one time all the great southern land masses were connected more or less completely. The name "Gondwana Land" has been given to an assumed great southern continent, existing in late Permian time, and embracing a large part of the present South American, African and Australian continents, as well as parts of India and Malaya. Just how long these connections remained is not entirely clear, but if they persisted into the Cretaceous, or early Tertiary, this would explain many of the apparently anomalous facts of the present distribution of the floras of the southern hemisphere.

We have also to take into account the great antarctic continent. At present this is practically destitute of any terrestrial

4 Cockayne, *loc. cit.*, p. 206.
5 Maiden, *loc. cit.*, p. 181.

vegetation, but there have been found fossils indicating the former presence of a vegetation related to that of South America and New Zealand. Further investigation may show that there was a northward extension of the present antarctic continent, with climatic conditions much more favorable for vegetation, than exists at present.

If further discoveries of fossils should show that, as in the northern hemisphere during the Tertiary, there was also in the south a practically uniform flora encircling the globe, this would make comprehensible both the resemblances and differences now existing in the floras of the southern land-masses.

Migrants from this common southern flora later completely shut off in the present widely separated countries, would in course of time show greater or less divergence from each other, depending upon the amount of change in their environment. It might be expected that in the cool humid climate of New Zealand, the evolution of the primordial southern types would be very different from those subjected to the hot and arid conditions of Western Australia, which is supposed to be the birthplace of most of the strictly Australian plant-types.

EASY GROUP THEORY

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THE report that the title of the chair of "differential and integral calculus" in the University of Paris has recently been changed to "the theory of groups and the calculus of variations" may tend to create a desire on the part of a larger group of scientific men to understand the essence of a mathematical group and the rôle which the group concept is assuming in modern mathematical developments. The fundamental importance of the concepts of differential and integral calculus in various fields of science has long been recognized, and the change of title noted above does not imply that the theory of groups and the calculus of variations tend to supplant the differential and integral calculus. It does, however, imply that the former subjects are also sufficiently fundamental and fruitful to merit prominent recognition in a leading mathematical center.

Paris may justly claim a very large share in the early development of group theory. A Parisian, A. L. Cauchy, is commonly regarded as the founder of this subject, while other Parisians, including A. T. Vandermonde and E. Galois, did important pioneering work in this field. Although J. L. Lagrange is commonly regarded as a French mathematician his pioneering work in group theory was done before he settled in Paris. The first separate treatise on this subject was written by a Parisian. This work appeared in 1870 under the title *Traité des substitutions et des équations algébriques* by C. Jordan.

In group theory as well as in differential and integral calculus the first extensive formal or abstract developments are due to English and German mathematicians. In the case of the latter subjects the authors of these developments, *viz.*, Newton and Leibniz, are commonly regarded as its founders. Fortunately this has not yet been done as regards the former subject. Notwithstanding the fundamental importance of formal developments and abstract formulations the real life of mathematics abides in its contact with the concrete. In the case of group theory this contact has been emphasized especially by S. Lie, F. Klein and H. Poincaré. The rapidly increasing prominence of this theory during the last half

century is largely due to the writings of these three men, who have been leaders also in various other lines of mathematical activity.

A dominating mathematical concept, like a dominating personality, has a charm of its own, and creates a kind of atmosphere which is as invigorating as that of a real university or that which emanates from any group of real scholars. A fundamental notion of a mathematical group is that "there is no new thing under the sun." It is true that we speak here of generators and generational relations, but the objects which are generated were members of the group since the beginning of time and will remain members thereof throughout eternity. We study the group to perceive this sameness in its various forms and to understand the relative properties of the various elements which unite to make a single element of the group.

The non-technical meaning of the term group suggests little as regards its technical meaning except the invariance of the number of its elements. In a non-technical group one usually thinks of the elements as units which may or may not have the power of reproduction. In the former case the elements thus produced are usually new elements of the group. In the technical group the elements have necessarily the power of uniting, but when they unite they neither produce any new element nor lose their own identity. The union merely exhibits the possible decomposition of an element of the group, or the different ways of securing *e pluribus unum*. Union, unity and stability constitute the triumvirate of the theory of groups. The stability here noted is not the stability of statics but the stability of dynamics. It is a kind of invariance under transformations.

What is perhaps of most interest in this connection as regards the non-mathematician is the question why the concept to which we referred above is so fundamental in mathematics. It is well known that mathematical developments have been largely guided by the desire to secure intellectual penetration into the workings of nature. Do we find in nature numerous instances of the union of elements of the same kind to produce an element of this kind which is really not new but belongs to a totality which has been clearly defined? For instance, one may think of the totality of the transformations of space subject to the condition that the distance between every pair of points in space remains invariant. It is evident that if one such transformation is followed by another the two together are equivalent to a single transformation of the totality in question. Hence we say that this totality constitutes a group.

It is also clear that the totality of the natural numbers when they are combined by addition has the property that no new number arises from the combination of any two of them, or from the combination of one with itself. In both this totality and in the totality of transformation noted in the preceding paragraph it is evident that if x, y, z represent three elements of the totality and if any two of them are supposed to be known then the third is completely determined by the following equation:

$$x\,y = z$$

The term group is commonly used in mathematics in the restricted sense that the third of any three elements is completely determined by such an equation where any two of them are supposed to be given. Moreover, it is usually assumed that when any three elements are combined the associate law is satisfied, but it is not assumed that the commutative law is necessarily satisfied when two of them are combined.

Even when these restrictions are imposed there are instances of groups almost wherever one turns. It is true that in the vegetable and the animal kingdoms one sees new elements arising in profusion, and mathematics is naturally called on to deal also with such conditions, but if one looks deep enough here there seems to be a union of elements without loss of identity of the elements, and there seems to be nothing new in the profound formal physical sense. Hence one may see some significance in the following statement made by Poincaré shortly before his death: "The theory of groups is, so to say, entire mathematics, divested of its matter and reduced to a pure form."

In the groups noted above the number of elements is infinite. As instances of a finite group we may consider the six movements which transform a fixed equilateral triangle into itself and the eight movements which transform a fixed square into itself. Such special instances are, of course, of little interest to the general scientist except as illustrations. The thing that may be supposed to command the interest even of the educated layman is the fact that these very evident considerations appertain to a profound mathematical theory.

Group theory did not arise from such obvious considerations. After it was partially developed as an autonomous science some of its more obvious applications received special attention. A certain degree of difficulty seems to create the most favorable atmosphere for scientific developments. In group theory this atmosphere was created by the n roots of the algebraic equation of the following form:

$$x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_n = 0$$

It is customary to speak of x as the unknown and to call this an equation of degree n in one unknown. As a matter of fact the equation has n roots and all of these are unknown, so that it is really an equation in n unknowns. The constant coefficients $a_1, a_2 \ldots a_n$ were known to be symmetric functions of these n unknowns before the subject of group theory was developed.

The mysterious appearance of n unknowns to take the place of the one which presents itself openly is perhaps sufficient to create an atmosphere suitable for scientific endeavors. At any rate, it was in this atmosphere that our subject arose and hence we shall note here a few of the early steps in its development. It is true that these steps were taken by men who seemed to have no idea that they were dealing with notions which had the widest applications in other fields of mathematical endeavor. In fact, the early explorers of group theory died long before any one realized that the notions with which they were dealing were destined to permeate a large part of the science of mathematics.

The n roots of an equation of degree n with constant coefficients constitute a group in the non-technical sense of the term, but the group of this equation is something very different and lies much deeper. It relates to a certain totality of permutations of these n roots, or substitutions on these n roots, leaving invariant every possible rational function of these roots which is equal to a constant, and having the property that if a rational function of these roots is invariant under these substitutions it is equal to a constant. These fundamental properties of the n roots of the equation in question were first noted by E. Galois, a French mathematician of great renown, although he died before reaching the age of twenty-one years. They were sufficiently difficult to create an atmosphere suitable for the development of our subject as an autonomous science.

A study of the permutations of n things might at first appear to promise little of importance. It is true that before the time of Galois attention had been called to this subject by Lagrange and Vandermonde in connection with the question under what condition a rational function on n variables can be expressed rationally in terms of another such function, but it was not until long after the days of Galois that mathematicians began to realize the fundamental importance of this subject in the study of a large variety of mathematical questions. When the substitutions arising from these various permutations were studied by themselves they were seen to combine according to laws which are found almost everywhere when the data are sufficiently connected to admit mathematical treatment.

The reader who has given little attention to mathematical developments may be inclined to ask, If the notion group is so fundamental why did the ancients and even such eminent later thinkers as Descartes and Newton pay no explicit attention to it? Why does the theory of groups not have an ancient prototype like differential and integral calculus, whose prototype is found in the method of exhaustion of the ancient Greeks? Does it appear reasonable that a subject founded only three quarters of a century ago should really deserve such a dominating position in modern mathematics as is claimed for group theory in what precedes the present paragraph? Does the history of mathematics present any other instance of the sudden rise of a dominating concept extending into practically all the large branches of mathematics?

The fact that the last of these questions must be answered in the negative tends to enhance the interest in the others. This negative answer calls also for a word of caution for there is danger that the reader might infer from it that the subject of group theory has greater merit than really belongs to it. It seems that mathematical developments have always been guided by the group concept. In the words of Poincaré "the ancient mathematicians employed groups in many cases without knowing it." The main question in mathematical developments is that one gets on the right road. The ability to explain why one has chosen this road is of secondary importance. In fact, the best teacher is frequently unable to give a good account of his methods while a much inferior teacher may be able to talk glibly about methods.

Group theory is largely a method and those who are studying this subject by itself may be compared with those who are devoting their attention to methods of teaching. Just as the latter are not necessarily the best teachers so the former are not necessarily the best mathematical investigators. Possibly the bacteria which have tended to make the teachers colleges such a prominent feature of our modern universities have also caused the emphasis on group theory in modern mathematics. Just as some of our best teachers have never read a work on methods of teaching so some of the best mathematical investigators have never secured a speaking acquaintance with the notion of group. In both cases the real essence of the subject has been acquired unconsciously, or, at least, without the development of a formal language relating thereto.

The fact that modern mathematicians emphasize the group concept while the ancient and medieval mathematicians did not do this does not imply a change of mental attitude. Naturally the modern mathematicians secured a somewhat deeper insight into various subjects and thus discovered evidences of groups

which were unknown to the older mathematicians. Inspired by these groups they developed also the theory relating to the groups which the ancients used implicitly, but it is questionable whether the modern mathematicians would have developed a theory relating to the latter if they had not been inspired by the former. At any rate, they did not take any steps towards such a theory before they had this additional motive. These observations may serve as partial answers to questions raised above relating to the late development of our subject as an autonomous science.

The heading of the present article suggests that some of the developments of our subject can not be properly called easy. In fact, by far the larger part of these developments presuppose a rather extensive technical knowledge and hence they are unsuited for a popular article. Among all the scientists the mathematician works usually at the greatest distance from his postulates, and hence he has the greatest difficulty to exhibit the results of his toil to the public in the hope of securing appreciation, which he craves with the others of his fellowmen. In group theory this distance has become especially long even for a mathematical subject, but this theory does extend also into the experiences of all thoughtful persons. The present article aims merely to direct attention to the richness of the mathematical developments which have contact with these particular experiences and thus to secure an easier approach to some of this richness.

If a group contains a finite number of elements this number is called the *order* of the group. For instance, the 24 different movements of space which transform a cube as a whole into itself but interchange some of its parts constitute a group of order 24. The most elementary group of a given order g is cyclic; that is, it is composed of the powers of a single one of its elements. For instance, the g numbers which satisfy the condition that the gth power of each of them is equal to unity constitute this group of order g, where g is any natural number. It is evident that the 24 different movements which transform a cube into itself are not powers of a single one of them. Hence they constitute a non-cyclic group of order 24. In fact, none of the elements of this group has to be raised to a higher than the fourth power in order to obtain unity, or the identity.

One of the fundamental problems of abstract group theory is the determination of all the possible groups of a given order g. It was noted above that there is one and only one cyclic group of every possible order g. When g is a prime number there is no other group of this order. This is also sometimes the case when g is composite but there is no upper limit to the number of groups

which may have the same composite order. That is, it is always possible to find a number g such that the number of the different abstract groups of order g exceeds any given finite number. In addition to the two groups of order 24 noted above there are 13 others, which were first completely determined in 1896 by the present writer. The lowest order for which the number of groups exceeds the order is 32. There are 51 distinct groups of this order.

The verification of several of these statements would carry us beyond easy group theory. They may serve, however, to exhibit a type of inquiry relating to our subject. Fortunately, some of the most important and far-reaching phases of this subject are also the easiest. For instance, the group of all the transformations of space which leave invariant the distances between every pair of points can easily be comprehended. Those geometric figures which can be transformed into each other under this group may be called equivalent and we may confine our attention to the study of geometric properties which remain invariant under the transformation of this group. We thus obtain a body of knowledge commonly called *Euclidean Geometry*, but this term is also often used with different meanings. Following the custom introduced by Gauss some still use it to denote all the geometry in which the parallel postulate is assumed.

It is clear that in geometry it is undesirable to endeavor to study every figure as an individual since one could not make much progress in this way. What people have always done in this subject is to confine their attention to invariants under certain infinite groups of transformations. It is true that the ancients did not specify these groups and that we do not usually do this now in a first course in elementary geometry, but for the advanced student, at least, the developments become much clearer if this specification is explicitly made. If we add to the transformations noted above those which do not preserve the size of the figures but do preserve their angles, so that all similar figures are regarded as equivalent, we obtain a larger group, which has been called the principal group of geometry. The body of knowledge relating to the invariants of this group is commonly known as *Elementary Geometry*. In particular, all circles are equivalent in this geometry and all squares are also equivalent here. Some writers call this geometry Euclidean Geometry. This is done, for instance, on page 61, volume 2, Pascal's *Repertorium der höheren Mathematik*, 1910.

These observations relating to the groups of geometry may serve also to support the implication noted above that group theory is often a kind of mathematical luxury. One can frequently get along without a knowledge of this subject where a knowledge

thereof would add greatly to the intellectual comfort. The fact that the mathematical world traveled far without making explicit use of this subject which now receives so much emphasis in work closely related to that which they were doing is perhaps best explained by viewing the matter from this standpoint. It need scarcely be added that group theory has also served to point out the way to easier methods of attack and to more powerful means of penetration, but this applies more especially to the more difficult group theory and hence lies outside the domain to which the heading of the present article relates.

In the opening sentence of this article we alluded to the fact that in the University of Paris there is now a chair entitled "the theory of groups and the calculus of variation." This should not be construed to mean that the developments of these two subjects have as yet much in common. In fact, there are few large mathematical subjects whose developments exhibit as little explicit use of group theory as those of the calculus of variations. Possibly the title noted above indicates that there will soon be a change in this direction. This title also raises the question whether our larger American universities should not have more chairs devoted to special subjects. The creation and occasional renaming of such chairs would tend to direct attention to leading investigators in various fields, an attention which often needs cultivation on the part of administrative officers.

THE HISTORY OF THE CALORIE IN NUTRITION

By MILDRED R. ZIEGLER

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THE nomenclature of a science is of vital importance; it is intimately bound up in the subject itself. Special technical words are used to describe the phenomena which are being studied. Lavoisier emphasized the importance of nomenclature in his "Traité Élémentaire de Chimie" (1789) when he stated: "Every branch of physical science must consist of three things; the series of facts which are the objects of the science; the ideas which represented these facts, and the words by which these ideas are expressed. Like three impressions of the same seal, the word ought to produce the idea, and the idea to be a picture of the fact . . .; we can only communicate false or imperfect impressions of these ideas to others, as long as precise terms are lacking."

The calorie as defined in the science of nutrition is a measure of food value. The significance of the word calorie as thus used to-day is not the same as its import when first introduced into the French language. To the student of nutrition the word connotes something quite different from the term as employed by the physicist. It is the amount of a food substance which on combustion in the body will yield energy—heat or work—equivalent to a calorie as understood by the physicists. Even the term as employed by the latter to-day has undergone a change from its original meaning (1845). As first defined the calorie represented the amount of heat required to raise one *kilogram* of water through one degree centigrade. It is well known that the same term now means the amount of heat required to raise one *gram* of water through one degree centigrade. The calorie, then, has had—and still does have—two somewhat unlike meanings according as the gram or kilogram of water is the unit of mass, the temperature of which is being changed and the energy required for this change is being considered. Both of these meanings are preserved in the scientific literature of to-day, the larger unit being designated as a large calorie and written Calorie.

It is quite evident that either the small calorie or the large Calorie may be the more convenient unit with which to express heat change depending upon the magnitude of the change being studied. The physicist in expressing the amount of energy supplied in the form of heat required to raise one gram of water from its freezing point to its boiling point obviously is dealing with a relatively small energy change which if expressed in heat units, as discussed above, is in the neighborhood of one hundred calories. In such cases the little calorie is the convenient unit to employ; on the other hand experiments in the field of nutrition have demonstrated that the energy changes are of such magnitude that the Calorie is the more convenient unit for expressing them quantitatively.

The derivation of the word is very interesting; it has developed from the old French word "calorique" which was derived from the Latin term "calor." Lavoisier introduced "calorique," which was defined at that time as an elastic fluid containing the hidden cause of the sensation of heat and to which the phenomena of heat were attributed. This meaning was abandoned with the theory to which it belonged. As far as a review of the literature reveals Bouchardat (1845) was probably the first to define it according to the modern physical conception. In his "Physique élémentaire" we read: "Unité de chaleur—On designe sous le nom d'unité de chaleur ou de calorie celle qui est nécessaire pour élever 1 kilogram d'eau d'un degré du thermomèter centigrade."

The idea of measuring heat in this way had been in general use for some time, but the word calorie had not been introduced earlier.

Pouillet (1832) in his "Physique" defined the heat liberated by combustion of different substances as "Élévation de témperature que 1 gr. de chaque substance en se brûlant avec l'oxigène communiquerait a 1 gr. d'eau." He ascribed the value 6195° to alcohol which checks closely with its caloric value as now known. Although the French had coined the word in the year 1845, it apparently was not in general use for some time; for in 1852 Favre and Silbermann[1] in an article on heat wrote: "We shall repeat that the unit which we have adopted is that adopted by all physicists, that is, the quantity of heat necessary to raise 1 gram of water 1 degree and which they call unit of heat or calorie." The Germans evidently took the word from the French, but it is difficult to determine at what time. Gmelin (1817-19) in his

[1] Favre and Silbermann: *Ann. de chim. et phys.*, 1852, Ser. 3, xxxiv, 357.

"Handbuch der Chemie" uses the same idea as the calorie unit but refers to it as did Pouillet. As late as 1871 Senator[2] deemed it necessary in an article on heat production and metabolism to define the word "calorie" in a footnote.

According to a contributor to Murray's "New English Dictionary on Historical Principle" (1888), the word calorie was first introduced into English in 1870 by T. L. Phipson in his translation of "The Sun" by the French astronomer, Amédée Guillemin. Before this time the English had spoken of heat units which referred to Joule's mechanical equivalent of heat, *viz.*, 1 kilog. of water raised 1°C=423 metrekilogs. This was the term used in Frankland's[3] classic treatise "On the Origin of Muscular Power."

The derivation of the word calorie has not revealed its meaning; for that it is necessary to consider the history of animal heat, combustion and the potential energy of the foodstuffs. To the old scientists animal heat offered a difficult problem, surrounded with much mystery. They could not explain it by any known chemical or physical laws. They did not assign any cause to it, but described it as an innate quality, something "vital" situated in the heart and distributed to the body by the blood vessels (Plato, Aristotle, Galen). The principal function of the blood was to distribute the heat, while the great function of respiration was to cool this distributing medium. Mechanical and chemical notions were accorded to heat production. As a history of the calorie is concerned only with the chemical theories, the mechanical ones described by Haller (1757)[4], Boerhaave (1709)[5] and contemporaries will not be discussed here. Willis (1670)[6] was probably the first to consider an idea of combustion in heat production. He said that there was a "combustion" in the blood dependent upon fermentation excited by the combination of different chemical substances. All the chemists of the time considered animal heat a product of a "fermentation" occurring in the blood while in the heart. Willis' term "combustion" was not in accord with the modern conception in which oxygen is essential, as this element had not been discovered. A more correct opinion was enunciated by Mayow (1674)[7] who had experimented on the elements of the

[2] Senator: *Centralbl. f. d. med. Wiss.*, 1871, IX, 737, 753.

[3] Frankland: *London, Edinburgh, and Dublin Phil. Mag. and Jour. of Sc.*, 1866, xxxii, 182.

[4] Haller: "Elementa Physiologiæ," 1757.

[5] Boerhaave: "Aphor. cum Notis Swieten," pp. 382-675.

[6] Willis: "De Accensione Sanguinis," 1670.

[7] Mayow: "Tractatus Quinque," Oxonii, 1674.

air and described a "nitro-aerial spirit" (oxygen). He held that the function of respiration was not to cool the blood but to enable this fluid to absorb nitro-aerial gas for generating heat. Mayow's theory did not appear to make any considerable impression upon his contemporaries. It was not until Joseph Black's (1755)[8] experiments on fixed air were performed that more correct ideas prevailed. He showed that the gas expired from the lungs is the same as that produced by combustion of fuel, thus establishing a relationship between combustion and respiration. Black was forced to relinquish his theory by his contemporaries who claimed that if the lungs were the sole seat of combustion the amount of heat produced therein would be so great that the vitality of the organ would be destroyed.

The production of heat by a combustion of foodstuffs was merely suggested at this time (1677) with no air of conviction that such could be the case. It appears that Descartes should receive the credit for first suggesting the correct theory regarding heat production in the animal body in his "De Homine" (1662). He thought that the change produced in the food in the stomach was analogous to the heat produced when water is poured upon lime or aqua fortis on metals. Hunter (1761) in his dissertation "On Blood" incidentally remarks that "the source of heat is in the stomach." He had previously expressed dissatisfaction with all prevailing theories of animal heat. Hunter's idea is to be regarded merely as his suggestion, with as yet no clear-cut data to justify its assumption of the rank of an established theory.

It remained for Lavoisier, the father of modern chemistry, to prove by his carefully performed experiments that animal heat is not caused by any mystical "vital force" as the ancients believed, but is a phenomenon analogous to the burning of a candle, namely, the combustion of carbon. He repeated, verified and added experiments to those of Black and Priestley, and explained more explicitly than had ever been done before the source of animal heat. In 1780 in his "Mémoire sur la Chaleur" published in collaboration with Laplace he gave in detail the theory of heat essentially as we have it to-day. By means of the calorimeter the heat evolved during the formation of a definite quantity of carbonic acid was compared with that produced during the formation of the same amount of this compound during respiration. These investigators saw that in such transformations identical amounts of heat were produced. They concluded that animal heat is derived from the oxidation of the body's substance.

[8] Robison: "Joseph Black," Edinburgh, 1803.

The publications of Lavoisier's time and before that had spoken of heat as "chaleur." Pouillet (1832), the physicist, remarked: "Scientists confused the cause of heat with its effect. They called it chaleur, fluide igné, matière du feu. Finally in reforming the chemical nomenclature Lavoisier, Bertholet, Morveau and Fourcroy have called it calorique. This term was adopted by the physicists of the time; and they reserved the word 'chaleur' to designate the science which treats of the properties, effects and laws 'du calorique.'"[9] An interesting use of "calorique" is found in the "Mémoire sur la Respiration des Animaux" published in 1789 by Lavoisier and Seguin. They state, "1. Que le calorique (matière de chaleur) est un principe constitutif des fluides (Sous ce nom générique nous comprenons les airs et les gaz.) et que c'est à ce principe qu'ils doivent leur état de'expansibilité, leur élasticité, et plusieurs autres des propriétés que nous leur connaissons."[10] There is no reference to a heat unit, calorie, in Lavoisier's publications. He defines the amount of heat in terms of the weight of ice melted in a given experiment.

Although the early physiologists suggested the correct source of animal heat, it is significant that they considered heat a simple chemical reaction, as stated by Descartes. Apparently they had no idea of a combustion as understood in the modern sense occurring in the tissues, for they did not consider the source of animal heat in starvation. Even physiologists of 1803 like Richerand do not consider starvation in their texts.

Lavoisier taught us the true cause of animal heat, but he could not explain the theory as to-day because the law of the conservation of energy had not been formulated. Joule (1844) by his masterly researches evaluated the mechanical equivalent of heat, and largely on this basis Mayer (1845) gave expression to the law of conservation of energy, the application of which was made by Helmholtz. Energy cannot be destroyed or created. As even the ancient Greek Democritus (370 B. C.) once said, "Nothing can ever become something nor can something become nothing"—*ex nihilo nihil fit, et in nihilum nihil potest reverti.*

Dulong, Depretz, Regnault, Reiset, Pettenkofer and Voit contributed considerable to the study of animal heat and in turn helped to perfect the calorimeter. It remained for Rubner[11] to

[9] "Chaleur" probably would be translated thermodynamics and "du calorique" heat.

[10] Lavoisier et Seguin: "Mémoire sur la Respiration des Animaux," 1789.

[11] Rubner: *Zeit. f. Biologie,* 1883, xix, 313; 1885, xxi, 250; 1886, xxii, 40; 1894, xxx, 73.

prove that physiological activity in the animal body is no exception to the operation of the law of conservation of energy. He showed that chemical change is the cause of animal heat. He discovered that the animal is a living calorimeter in which food, when burned, changes into another form of energy. Rubner, experimenting with dogs, measured the body's income and output of energy, and determined the relation of heat produced by oxidation of the foodstuffs ingested to the products which are given out. This figure he compared with the energy produced as measured by the calorimeter and found an agreement within one per cent. This remarkable result has since been confirmed by other investigators who have been aided by modern methods, the refinements of which are difficult to describe adequately. Rubner's important conclusions are that energy is not destroyed or created by the living organism; that the foodstuffs are oxidized within the body in a manner similar to their oxidations in a chemical laboratory. The law of conservation of energy therefore applies to the animate as well as to the inanimate world.

When calories are mentioned in nutrition, it is from the point of view of food fuel value. The calorie value of a diet is a factor of great importance in nutrition. Frankland (1866) was the first to determine this for various foodstuffs by oxidizing them in a calorimeter. He did not express the results in "calories" but rather as "heat units" (*loc. cit.*) which had the same value. Stohmann (1879)[12] and Rubner (1883) were apparently the first to use the term calorie as it is now applied in the science of nutrition. Rubner made three outstanding contributions regarding the calorie in nutrition: (1) He applied its present day meaning to the term; (2) he determined the caloric value of protein, fat and carbohydrate, figures which are widely used in determining the energy content of a diet; (3) he drew the distinction between the absolute and physiological heat values of foods. By absolute heat value he meant the amount of heat yielded by a substance when oxidized in a bomb calorimeter; the amount of heat produced by the substance in question when burned within the animal body he regarded as its physiological heat value. These values may or may not be identical, a fact which is of fundamental importance in the science of nutrition.

Calorie as a mere word explains nothing. It is a symbol for an idea, however, which, as we have seen, has undergone changes brought about by the development of several sciences. Ancient

[12] Stohmann: *Journ. f. prakt. Chem.*, 1879, xix, 115.

and hazy notions regarding the phenomenon of fire and combustion first contributed to this concept, placed on a firmer foundation by the clarifying influence of Lavoisier. The broad generalization regarding force in nature, receiving its impression in the law of the conservation of energy, played its rôle in the evolution of the idea and should probably be regarded as the most important factor contributing to the development of this notion as it exists to-day. The history of the calorie in nutrition, therefore, is wrapped up in the history of nutrition itself and the fundamental natural sciences upon which this branch of knowledge rests.

SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE IV—ANTS, THEIR DEVELOPMENT, CASTES, NESTING AND FEEDING HABITS

II

There is throughout the animal kingdom, as I believe Espinas was the first to remark, a clear correlation on the one hand between a solitary life and carnivorous habits and on the other hand between social habits and a vegetable diet. The beasts and birds of prey, the serpents, sharks, spiders and the legions of predacious insects all lead solitary lives, whereas the herbivores, rodents, granivorous and frugivorous birds and plant-eating snails and insects are more or less gregarious. Man himself is quite unable to develop populous societies without becoming increasingly vegetarian. Compare, for example, the sparse communities of the carnivorous Esquimaux with the teeming populations of the purely vegetarian Hindoos. The reasons for these correlations are obvious, for plants furnish the only abundant and easily obtainable foods and, at least in the form of seeds and wood, the only foods that are sufficiently stable to permit of long storage. In the previous lectures I have shown that the social beetles and bees are strictly vegetarian and that the social wasps, though descended from highly predatory ancestors, are nevertheless becoming increasingly vegetarian like the bees. The ants exhibit in the most striking manner the struggle between a very conservative tendency to retain the precarious insectivorous habits of their vespine ancestors and a progressive tendency to resort more and more to a purely vegetable regimen as the only means of developing and maintaining populous and efficient colonies. Anthropologists have distinguished in the historical development of human societies six successive stages, designated as the hunting, pastoral, agricultural, commercial, industrial and intellectual. Evidently the first three, the hunting, pastoral and agricultural, are determined by the nature of the food and represent an advance from a primitive, mainly flesh-consuming to a largely vegetarian regimen. Lubbock showed that the same three stages occur in the same sequence in the phylogenetic history of the ants. At the present time we are able to give even greater precision to his outlines of this evolution.

[1] Lowell Lectures.

All the primitive ants are decidedly carnivorous, that is predatory hunters of other insects. That this must have been the character of the whole family during a very long period of its history is indicated by the retention of the insectivorous habit, in a more or less mitigated form, even in many of the higher ants. Always striving to rear as many young as possible, always hungry and exploring, the ants early adapted themselves to every part of their environment. They came, in fact, to acquire two environments, each peopled by a sufficient number of insects, arachnids, myriopods, etc., to furnish a precarious food-supply. Most of the ants learned to forage on the exposed surface of the soil and vegetation and became what we call epigæic, or surface forms, while a smaller number took to hunting their prey beneath the surface of the soil and thus became hypogæic, or subterranean. Many of the latter are very primitive but their number has been repeatedly recruited from higher genera, which by carrying on all their activities within the soil have found a refuge and surcease from a too strenuous competition with the epigæic species. We have here some very interesting cases of convergence, or parallel development, since the underground habit has caused the workers, which rarely or never leave their burrows, to lose their deep pigmentation and become yellow or light brown and to become nearly or quite blind. As will be evident in the course of my discussion, the tendency towards vegetarianism is apparent among both the epigæic and hypogæic forms.

The ants belonging to the oldest and most primitive subfamilies, the Ponerinæ, Dorylinæ and Cerepachyinæ and also to many of the lower genera of Myrmicinæ, feed exclusively on insects and therefore represent the hunting stage of human society. Owing to the difficulty of securing large quantities of the kind of food to which they are addicted, many of the species form small, depauperate colonies, consisting of a limited number of monomorphic workers. Many of these species lead a timid, subterranean life. In the size of their colonies, which may comprise hundreds of thousands of individuals, the Dorylinæ alone constitute a striking exception, but one which proves the rule. These insects, known as driver, army or legionary ants and very largely confined to Equatorial Africa and tropical America, are strictly carnivorous, but being nomadic and therefore foraging over an extensive territory, are able to obtain the amount of insect food necessary to the growth and maintenance of a huge and polymorphic population. They are the famous ants whose intrepid armies often overrun houses in the tropics, clear out all the vermine and compel the human inhabitants to leave the premises for a time. In Africa they have been known to kill even large domestic animals when they were tethered or penned up and thus prevented from escaping.

The pastoral stage is represented by a great number of Myrmicine and especially of Formicine and Dolichoderine ants which live very largely on "honey-dew." This sweet liquid, concerning the origin of which there was much speculation among the ancients, is now known to be the sap of plants and to become accessible to the ants in two ways First, it may be excreted by the plants from small glands or nectaries ("extrafloral nectaries") situated on their leaves or stems, where it is eagerly sought and imbibed by the ants. Second, a much more abundant supply is made accessible by a great group of insects, the Phytophthora, comprising the plant-lice, scale-insects, mealy-bugs, leaf-hoppers, psyllids, etc., which live gregariously on the surfaces of plants. These Phytophthora pierce the integument of the plants with their slender, pointed mouth-parts and imbibe their juices which consist of water containing in solution cane sugar, invert sugar, dextrin and a small amount of albuminous substance. In the alimentary canal of the insects much of the cane sugar is split up to form invert sugar and a relatively small amount of all the substances is assimilated, so that the excrement is not only abundant but contains more invert and less cane sugar. This excrement or honey-dew either falls upon the leaves and is licked up by the ants or is imbibed by them directly while it is leaving the bodies of the Phytophthora. Many species of ants have learned how to induce the Phytophthora to void the honey-dew by stroking them with the antennæ, protect and care for them and even to keep them in specially constructed shelters or barns. Some ants have acquired such vested interests in certain plant-lice that they actually collect their eggs in the fall, keep them in the nests over winter and in the spring distribute the hatching young over the surface of the plants. Linnæus was therefore justified in calling the plant-lice the dairy-cattle of the ants ("*hæ formicarum vaccæ*"). This dairy business is, in fact, carried on in all parts of the world on such a scale and with so many species of Phytophthora that it constitutes one of the most harmful of the multifarious activities of ants. Their irrepressible habit of protecting and distributing plant-lice, scale-insects, etc., is a source of considerable damage to many of our cultivated plants and especially to our fruit-trees, field and garden crops. Ants mostly attend Phytophthora on the leaves and shoots of plants, but quite a number of species are hypogæic and devote themselves to pasturing their cattle on the roots. Thus our common garden ant (*Lasius americanus*) distributes plant-lice over the roots of Indian corn.

The habit of keeping Phytophthora was probably developed independently in many different genera, and it is easy to see how the habit of feeding by mutual regurgitation among the ants themselves might have led to the behavior I have been describing. Cer-

tainly the genera that have developed trophallaxis among the adult members of their colonies are the very ones which most assiduously attend the Phytophthora. And it is equally certain that the latter habit is very ancient, because it was already established among the ants of the Baltic Amber during Lower Oligocene times and that, as we have seen, was many million years ago.

The dairying habit has led to an interesting specialization in certain species known as "honey ants," which inhabit desert regions or those with long, dry summers. These ants have found it very advantageous to store the honey dew collected during periods of active plant growth, and as they are unable to make cells like those of wasps and bees, have hit upon the ingenious device of using the crops of certain workers or soldiers for the purpose. In all ants, as we have seen, the crop is a capacious sac, but in the typical honey ants it becomes capable of such extraordinary distention that the abdomen of the individuals that assume the rôle of animated demijohns or carboys, becomes enormously enlarged and perfectly spherical. Such "repletes" (Fig. 66) are quite unable to walk and therefore suspend themselves by their claws from the ceilings of the nest chambers. When hungry the ordinary workers stroke their heads and receive by regurgitation droplets of the honey dew with which they were filled during seasons of plenty. The condition here described, or one of less gastric distention, has been observed in desert or xerothermal ants in very widely separated regions and belonging to some nine different genera of Myrmicinæ, Formicinæ and Dolichoderinæ (Myrmecocystus and Prenolepis in the United States and Northern Mexico, Melophorus, Camponotus, Leptomyrmex and Oligomyrmex in Australia, Plagio-

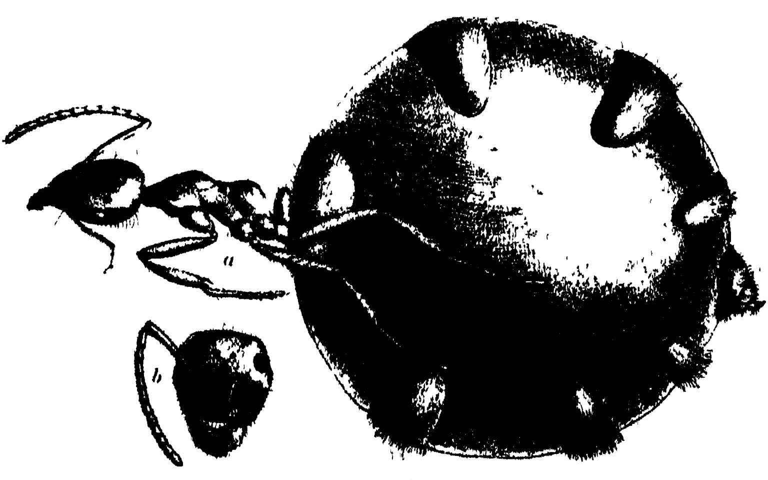

FIG. 66
Replete of honey ant (*Myrmecocystus melliger*) from Mexico. *a*, lateral aspect of insect; *b*, head from above.

lepis and Aëromyrma in Africa and Pheidole in Australia and the southwestern United States).

A more direct vegetarian adaptation is seen in many Formicidæ that inhabit the same desert or xerothermal regions as the honey ants. In such regions insect food is at no time abundant and is often so scarce that the ants are compelled to eat the seeds of the sparse herbaceous vegetation. At least a dozen genera, all Myrmicinæ, illustrate this adaptation: Pogonomyrmex, Veromessor, Novomessor and Solenopsis in America, Messor, Oxyopomyrmex, Goniomma, Tetramorium and Monomorium in the southern Palearctic region, Meranoplus in the Indoaustralian, Cratomyrmex and Ocymyrmex in the Ethiopian region and Pheidole (Fig. 57) in the warmer parts of both hemispheres. It was at one time believed that some of these ants actually sow around their nests the grasses and other herbaceous plants from which they gather the seeds, but this has been disproved. They are merely collected, husked and stored in special chambers or granaries in the more superficial and dryer parts of the formicary. Emery has shown that as food the proteids are preferred to the starchy portions of the seeds and are also fed to the larvæ *Messor barbarus*, the ant to which Solomon refers, is one of these harvesters. Probably none of them disdains insect food when it can be had. Nevertheless the adaptation to crushing hard seeds is so pronounced in certain genera that the mandibles have become distinctly modified. Their blades have become broader and more convex and the head has been enlarged to accommodate the more powerful mandibular muscles In certain forms (Pheidole, Messor, Novomessor, Holcomyrmex) the soldiers or major workers seem to function as the official seed-crushers of the colony

The harvesting ants can hardly be regarded as true agriculturists because they neither sow nor cultivate the plants from which they obtain the seeds Yet there is a group of ants which may properly be described as horticultural, namely the Attiini, a Myrmicine tribe comprising about 100 exclusively American species and ranging from Long Island, N. Y., to Argentina, though well represented by species only within the tropics. The tribe includes several genera (Cyphomyrmex, Apterostigma, Sericomyrmex, Myrmicocrypta, etc.) the species of which are small and timid and form small colonies with monomorphic workers, while others (Atta and Acromyrmex) are large and aggressive and form very populous colonies with extremely polymorphic workers. The Attas or parasol ants inhabit the savannas and forests of South and Central America, Mexico, Cuba and Texas. Their extensive excavations result in the formation of large mounds and often cover a considerable area (Fig. 67). According to Branner, a single mound of

the common Brazilian *Atta sexdens* may contain as much as 265 cubic meters of earth, and the population of a colony of this species, according to Sampaio, may number from 175,000 to 600,000 individuals. Of course, the size of the mounds varies with the depth of the excavations, which are much shallower in the rain-forests than in the dry savannas. From their mounds the ants make well-worn paths through the surrounding vegetation and frequently defoliate bushes or trees, cutting large pieces out of their leaves and carrying them like banners to their nests. The pieces are then cut into smaller fragments and built up on the floors of the large nest chambers (Figs. 68 and 69) in the form of sponge-like

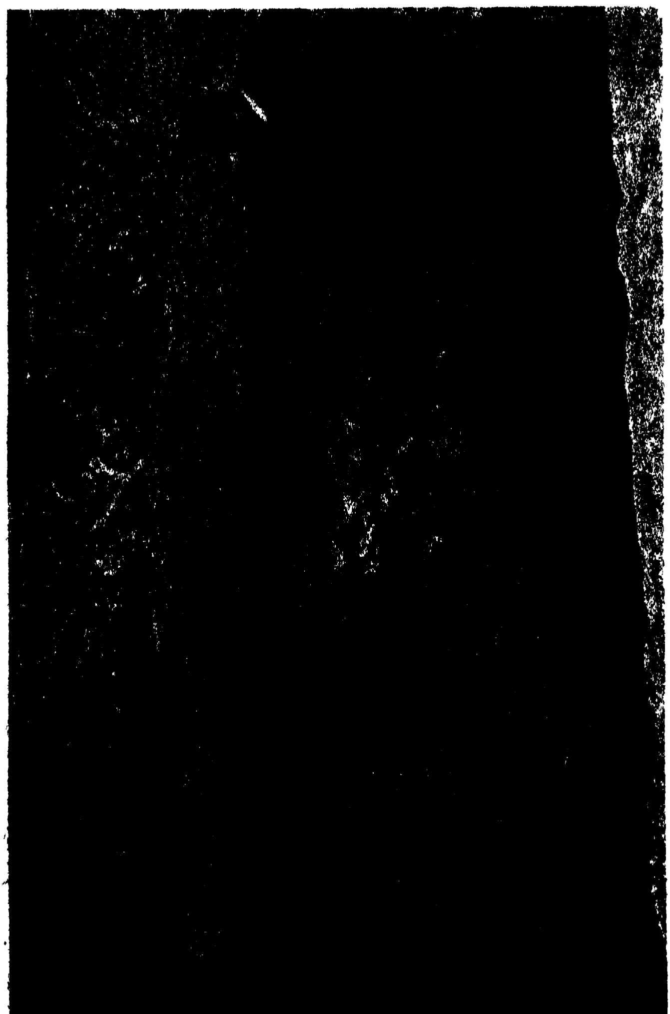

FIG. 68

Vertical section through the center of a nest of the Argentinian leaf cutter. *Atta vollenweideri*, showing the chambers containing the fungus gardens. (Photograph by Dr Carlos Bruch).

masses, which become covered with a white, mould-like fungus mycelium (Figs. 70 and 71). The latter is treated in some unknown manner by the smallest, exclusively hypogæic caste of workers, so that the hyphæ produce abundant clusters of small, spherical dwellings, the bromatia (Fig. 72), which are eaten by the ants and fed to their larvæ. Each species of Attiine ant cultivates its own particular fungus and no other is permitted to grow in the nest. That the bromatia are really anomalous growths induced

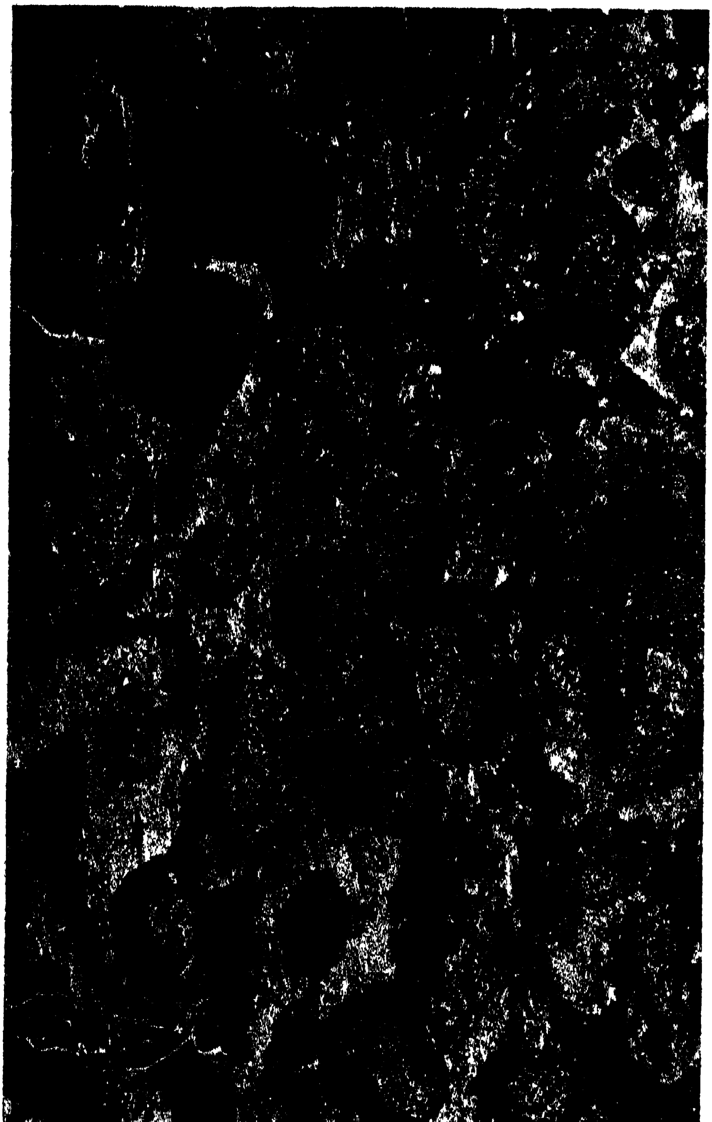

FIG. 69

Portion of nest of *Atta vollenweideri* shown in Fig. 68, more enlarged to show the sponge-like fungus-gardens *in situ* in the chambers. About one eighth natural size. (Photograph by Dr Carlos Bruch)

by the ants is indicated by the fact that they do not appear when the fungus is grown in isolation on artificial media. Alfred Moel-

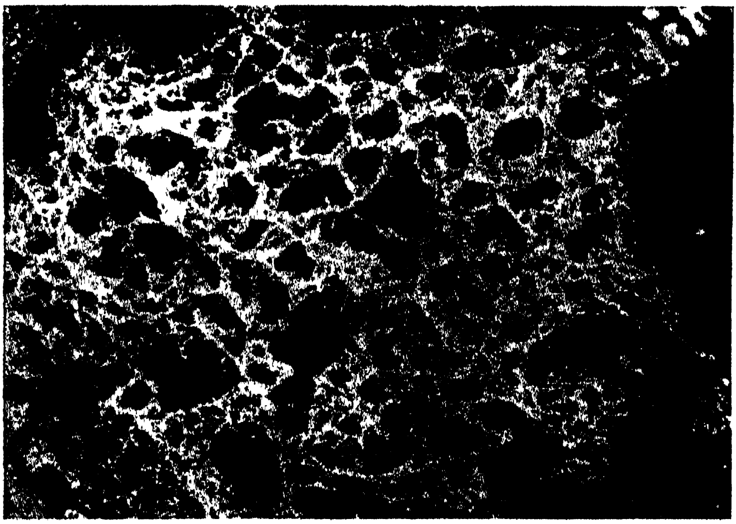

FIG 70
Portion of fungus garden of the Texan leaf-cutting ant (*Atta texana*). About one half natural size.

FIG. 71
Fungus garden built in a Petri dish by a colony of Apterostigma in British Guiana. Natural size. (Photograph by Mr. Tee-Van.)

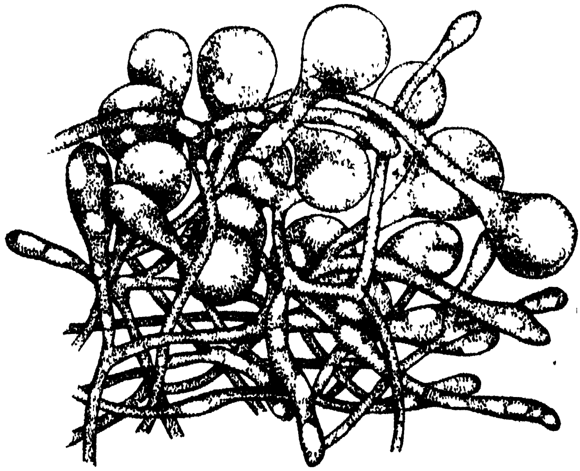

FIG. 72
Modified mycelium (bromatium) of fungus cultivated by the Argentinian *Moellerius heyeri.* The globular swellings of the hyphæ are produced by the ants (After Carlos Bruch.)

ler, who was the first to cultivate these fungi, regarded them as belonging to the Agarics and named one of them *Rozites gongylophora.* Either the ants prevent the mushrooms from appearing, or, more probably the subterranean conditions under which the mycelium is cultivated are unfavorable to their development. Moeller was also unable to obtain the mushrooms in his cultures, but found those of Rozites growing on the surface of an abandoned Acromyrmex nest. That the fungi cultivated by the various Attiini belong to several different genera is shown by Bruch and Spegazzini who have recently been able to identify the mushrooms of the fungi cultivated by several Argentinian Attiini. *Acromyrmex lundi,* e. g. cultivates *Xylaria micrura* Speg., *Moellerius heyeri. Poroniopsis bruchi* Speg. and *Atta vollenweideri,* a gigantic Agaric, *Locellina Mazzuchii* Speg. (Fig. 73).

The lower genera of the Attiini differ in many particulars from such highly specialized forms as Atta and Acromyrmex. Their nests are smaller and there are differences in the gardens and the substratum, or substances on which the fungi are grown. The species of Trachymyrmex suspend the garden from the ceiling of the nest chamber instead of building it on the floor, and in some species of Apterostigma it is enclosed in a spherical envelope of dense mycelium, so that, except for its larger size, it much resembles the silken egg-case of a spider. These ants and others, such as Cyphomyrmex and Myrmicocrypta, use the excrement of other insects, especially of caterpillars, as a substratum for the gardens, and one species, *Cyphomyrmex rimosus,* cultivates a very peculiar fungus (*Tyridiomyces formicarum* Wheeler), which does not grow

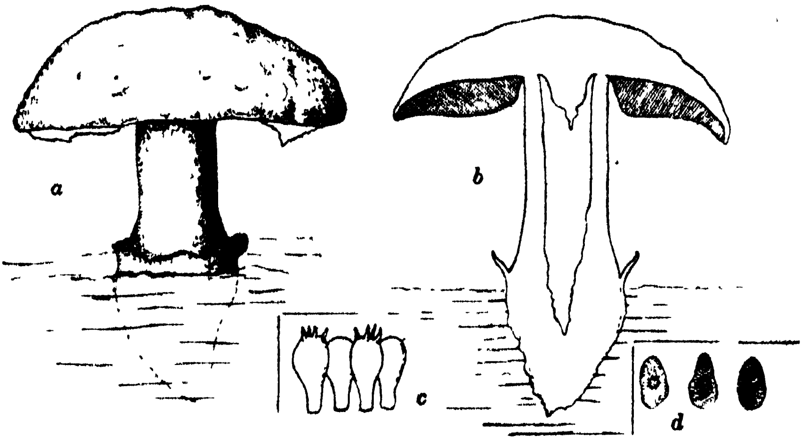

FIG. 73

a, *Locellina Mazzuchii* the gigantic fruiting phase (pileus 30 to 42 cm. in diameter!) of the fungus cultivated by the Argentinian leaf-cutting ant (*Atta vollenweideri*), *b*, section of same, *c*, basidia, *d*, spores (After C Speggazzini.)

in the form of a mycelium but of isolated, compact bodies, resembling little pieces of American cheese, and consisting of yeast-like cells. The same or a very similar fungus is grown by the species of Mycocepurus.

How do all these Attiine ants come into possession of the various fungi which they cultivate with such consummate skill. The question is, of course, twofold, since we should like to know how the individual colony obtains its fungus and how the ancestors of the existing Attiini first acquired the fungus-growing habit. The former question has been answered by the very interesting investigations of Sampaio, H. von Ihering, J. Huber and Goeldi on the Brazilian *Atta sexdens* and of Bruch on the Argentinian *Acromyrmex lundi*. The virgin queen of these species, before leaving the parental nest for her marriage flight, takes a good meal of fungus. The hyphæ, together with the strigil sweepings from her own body and, according to Bruch, also some particles of the substratum, are packed into her infrabuccal pocket, where they form a large pellet, which she retains till she has mated, thrown off her wings and made a small chamber for herself in the soil. She then casts the pellet on the floor of the chamber where its hyphæ begin to proliferate in the moist air and draw their nutriment from the extraneous materials with which they are mingled (Fig. 74*A*). The queen carefully watches the incipient garden and accelerates its growth by manuring it with her feces (*C* and *D*). She begins to lay eggs (Fig. 76 *A*) and even breaks up some of them and adds them to the garden, which soon becomes large enough to form a kind of nest for the intact and developing eggs (Fig. 74 *B* to *F*).

The young larvæ on hatching proceed to eat the mycelium and eventually pupate and emerge as small workers, which break through the soil, bring in pieces of leaves and add them to the garden. The care of the latter then devolves on the workers and the queen henceforth devotes herself to laying eggs. The colony is now established and its further development is merely a matter of enlarging the nest, multiplying the gardens and increasing the population. Thus Atta and Acromyrmex transmit their food-plants from generation to generation in a very simple manner, that is, merely by the queen's retaining, till she has established her nest chamber, the infrabuccal pellet consisting of her last meal in the colony in which she was reared. And there is every reason

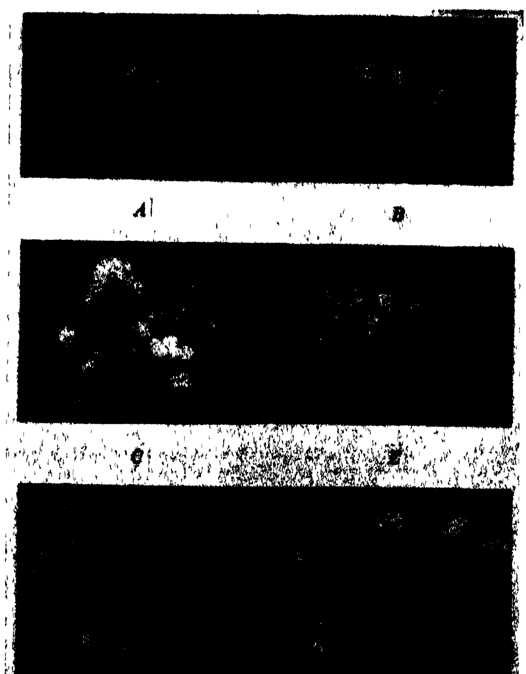

FIG. 74

Stages in the development of the fungus garden by the queen of the Argentinian *Moellerius hyeri*. *A*, pellet of substratum 36 hours after its ejection from the queen's infrabuccal pocket. The hyphæ have begun to grow. *B*, same pellet after 3 days, with 4 eggs; *C*, same pellet after 8 days, showing droplets of feces with which the queen manures the hyphæ. *D*, same pellet after 12 days, also showing droplets of feces; *E*, small fungus garden after 30 days, with 32 eggs; *F*, same after 40 days. The magnification of all the figures is very nearly 10 diameters. (Photographs by Dr. Carlos Bruch.)

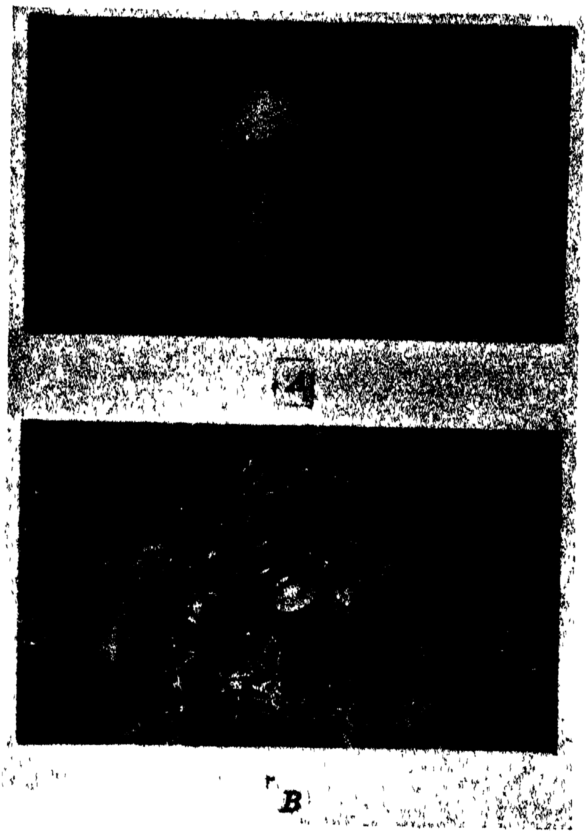

FIG. 75
A, an infrabuccal pellet of the queen *Moellerius heyeri* after cultivation for 36 hours on gelatine X10 *B*, eggs and pellets made of filter paper by a queen *Moellerius heyeri* that had failed to develop a fungus garden. X10 (Photograph by Dr. Carlos Bruch.)

to suppose that the same method of transmitting the fungus from the maternal to the daughter colonies is practiced by all the other genera of the tribe.

Of course, the answer to the question as to how the ancestors of the Attiini acquired their food-fungi in the first place must be purely conjectural. Yet certain observation by Professor I. W. Bailey and myself seem to indicate from what simple beginnings the elaborate fungus-growing habits may have been evolved. An examination of the infrabuccal pellets of the most diverse ants shows that in nearly every case they contain fungus spores or pieces of mycelium collected from the surfaces of their bodies or from the walls of the nest. Moreover, many ants have a habit of casting their pellets on the refuse heaps, or kitchen-middens of their nests, and Professor Bailey finds that in the case of certain African

A

B

C

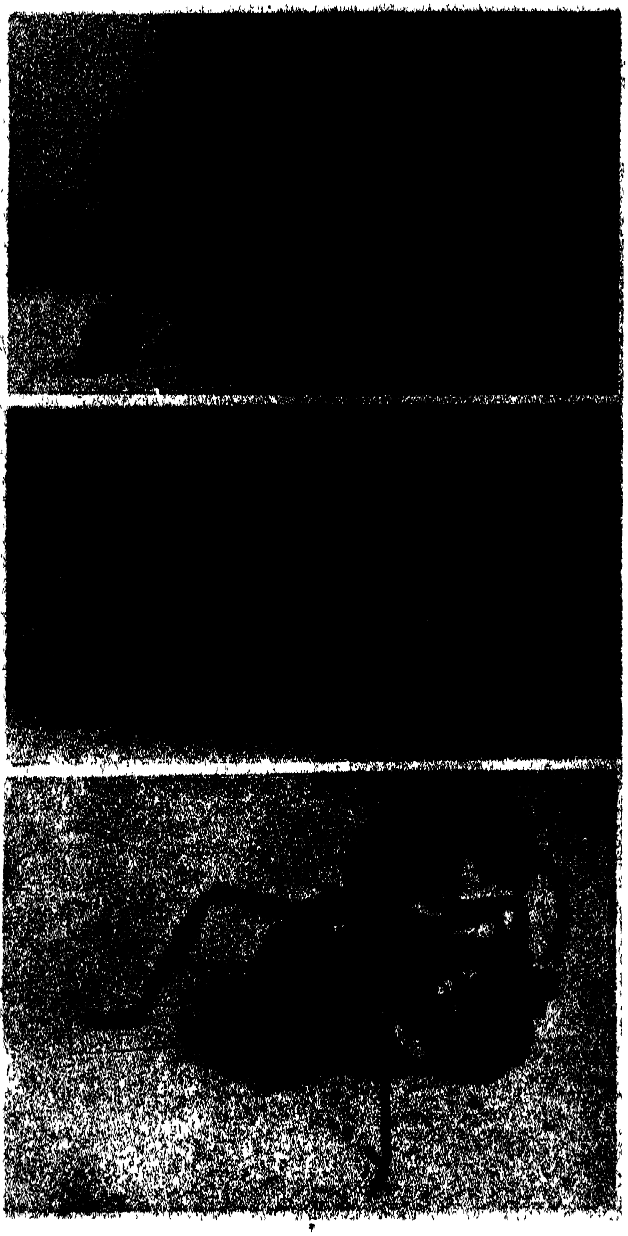

FIG. 76
Behavior of the queen of *Moellerius heyeri*. *A*, photographed in the act of laying an egg. The incipient fungus garden in which the egg will be placed is shown to the left resting on the floor of the nest chamber; *B*, queen placing an egg in the fungus garden which is sticking to the glass wall of the artificial nest. *C*, queen photographed in the act of placing a droplet of feces in the fungus garden. Magnification 5 diameters. (Photographs by Dr. Carlos Bruch.)

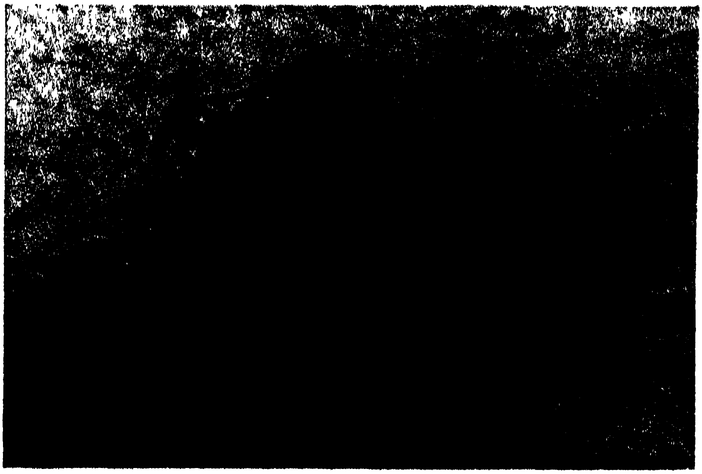

FIG 77

Two friendly queens of *Moellerius heyeri* caring for a single incipient fungus garden, which is adhering to the glass wall of the artificial nest X5. (Photograph by Dr Carlos Bruch.)

Crematogasters that live in the moist cavities of plants (Plectronia, Cuviera) the refuse heaps consist very largely of such ejected pellets and produce a luxuriant growth of aërial hyphæ which are cropped by the ants. From such a condition it is, perhaps, only a short step to the establishment of small gardens consisting at first of the pellets and later of these and accumulations of extraneous materials, such as the feces of the ants, those of caterpillars and beetles, vegetable detritus, etc., which might serve to enlarge the substratum and increase the growth of the fungus. The selection of particular species of fungi and their careful culture and transmission are evidently specializations that must have been established before the stages represented by even the most primitive existing Attiini could have been attained.

Whatever may have been the processes whereby the ancestral Attiini developed the fungus-growing habit, it must have originated in the more humid portions of the tropics, since nearly all the more primitive species of the tribe are still confined to the rain-forests. But certain species soon found that by sinking their galleries and chambers to a greater depth in the soil they could easily carry on their fungus farming even in arid regions. Thus some species of Moellerius, Trachymyrmex and Cyphomyrmex have come to live in the dry deserts of Arizona, New Mexico and northern Mexico, and as they can always find in such localities enough vegetable material for the substrata of their gardens, they have attained to a control of their environment and food-supply, which even the human inhabitants of those regions might envy.

THE MARINE FISHERIES, THE STATE AND THE BIOLOGIST

By WILL F. THOMPSON

MANY of the great marine fisheries of the world lie within the jurisdiction of more than a single sovereign country. The great North Sea fisheries, those of the Grand Banks, the salmon fisheries of the Fraser River (now nearly extinct), and the halibut fisheries of the North Pacific might be cited as examples. It would seem that this divided ownership has reacted most disastrously upon their care. Responsibility seems in such cases to be simply lost, not divided, and the net effect is that no one cares to sacrifice his own interests to maintain the fishery for the benefit of all. The splendid scientific work done in the North Sea contrasts vividly with the relative futility of the movement to conserve the vanishing bottom fisheries there by regulatory laws. There is simply no machinery capable of overriding the selfish interests of the few in each country, supplemented as it always is by the general suspicion one nation seems to think it necessary to have of every other nation.

The case seems far more hopeful, where there is no division of authority. And in many of our great states fisheries exist which are entirely under the legal control of a single state government. That is true in California, where there is not a single fishery common to both its own water and the waters of another state or country save of the sparsely inhabited desert of Lower California, to whose less exploited fisheries vessels often go from Southern California ports. There is thus no possibility of shirking responsibility—the care of its fisheries devolves upon California alone by virtue of the Constitution of the United States and of its geographical position. No question of nationalism can be involved, only that of sectionalism. As a result, the failure to conserve the fisheries for the people of the entire state can result only from faulty organization of public opinion and the lack of real proof of the necessity of conservation.

The securing of this proof of the condition of the fisheries has in California, as everywhere else, been recognized as a legitimate function of the responsible government, and *the proper execution of that function is vital to the success of any popular movement toward conservation.* Unlike the forests and the mines, private ownership has never been granted in the fisheries, save in the case

of oysters and those of certain fresh waters, and for that reason aroused popular opinion is entirely likely to control in the end. But powerful interests have grown up who will vigorously object to curtailment of their activities. Something tantamount to legal proof is necessary before what seems to them confiscation may be indulged in. And they have in the past shown a vitality which augurs ill for any but well-based movements toward conservation.

The general policy of conservation is, moreover, largely supported by men among the public who are not trained scientists and do not know the value of evidence. Their conclusions as to the existence of depletion may carry weight where, as in the case of birds and mammals, any honest man may observe conditions with his own eyes, and where powerful interests are not placed in jeopardy. But in the marine fisheries this is not true, for the fish are not easily observed and the evidence must come from statistical proof of comprehensive character. Under such circumstances the cry of conservation, raised hysterically and hastily, as is done even by scientists at times, must in the long run lead to failure and the injury of the cause at stake. And measures of regulation or restriction passed in response to pleas made on an insecure basis must in the end fail to justify themselves. So the acquirement of real knowledge, while a protection to the men legitimately engaged in exploitation, is equally such to the cause of conservation itself, for it should not only prevent this lack of balance and undue regulation, but it should prevent the growth of interests which must later be curtailed.

This necessity of knowledge was acknowledged by the fishery authorities of the State of California when they instituted the present system of observing the fisheries. Their action in this regard was based on the following facts: First, that enough accurate knowledge already exists to prove the susceptibility of marine fisheries in general to overfishing, second, that proof is required in the case of each individual fishery, and that there is no way of knowing the strain a species will stand save by submitting it to one; third, that such a course of action implies the duty of the state to maintain a constant and intelligent ward over its fisheries; and finally, that such a ward is possible and that it implies continuous and prolonged statistical and biological investigations.

In regard to the first point, the existence of proof that marine fisheries are exhaustible, we must turn to the oldest and best known of fisheries, namely those in North European seas. Contrary to the opinions of many, these great fisheries cannot justifiably be called ancient. The use of steam vessels began in 1880; the otter trawl first came into use in 1895, laying open to exploitation the depths of the ocean below fifty fathoms; while the means of mar-

keting and the extent of the demand increased equally with the recent great industrial expansion. The latter involved the development of railroads, the refrigeration of food products, the use of cans for their preservation, fast steamships to carry them, the growth of city life as a market, etc. Meanwhile, as cited by Jenkins ("The Sea Fisheries," 1920) as an illustration of the trend of the times, the number of fishing vessels in the port of Aberdeen, Scotland, increased 258 per cent. in the period 1897-1903, and according to the estimate of the same authority, agreeing with that of others, the efficiency of each steam trawler of to-day exceeds eight times that of the sailing trawler it displaced (aside from the independence the steamer has of weather and distance). The fisheries in other parts of the world are still more recent, and show the same great increase in apparatus although not necessarily in catch. If these facts are considered, it is impossible to doubt that, unless civilization comes to an abrupt pause, with the destruction of our highly developed transportation and of our industrialism which builds towns and markets, we are on the brink of an era of exploitation of our fisheries, and not at the crest of such an era. And the existence of overfishing now becomes a serious problem, for if the fisheries do show depletion, it is indeed a serious question whether they will, even in their more stable parts, survive the coming strain. Faith in our destiny and that of the world implies care of our resources of fish.

That they do show depletion in certain fisheries is now proved. The most clearly ascertained instances at present are those of the bottom fisheries. Thus the halibut in both the Atlantic and the Pacific has decreased with great rapidity. But the bottom fisheries of the North Sea for plaice and other allied species are, as Garstang ("The Impoverishment of the Sea," 1900) says, "not only exhaustible, but in rapid and continuous process of exhaustion." This conclusion has been seconded and supported by men who have, in the various countries around the North Sea, actually had the examination of the statistics in their care, as Heincke, Fulton, Thompson and others, such as Jenkins and Allen. And if these bottom fisheries already show exhaustion, since they are more stationary, are most highly valued, and were first sought for, it is not to be expected that "pelagic" fish will show otherwise upon the imposition of greater strain, even though they are more abundant. But in this connection, it must, indeed, be remembered that there is no accurate means of determining whether pelagic fish actually are more abundant than other fish in the ocean—although we do know that the cod and the herring, for instance, are not numberless, as some estimates have made them.

Against such a view there has been urged the objection that

the fisheries seem to be prospering and to be continuing on a firm basis. That fact may be granted, however, without conflicting with the above conclusions. It may be admitted that the total yield of the fisheries does not everywhere seem to decline, but it can be proved that continuously greater toil is required to obtain it. That this decreasing yield for the effort involved does not attract more attention should be understandable when it is considered that the cost of catching fish is but a fraction of the cost of distribution. Thus the fisherman may receive eight cents per pound where the retailer asks forty cents, and doubling the fisherman's price would add but a fifth to the retailer's price. The cost of obtaining the fish could be multiplied many fold without seriously affecting the final price to the consumer. The latter is, moreover, willing to pay high prices for a product to which he has become accustomed, and the rarer it is the more he will pay. The increase in initial cost does not seem, in fact, to be of the greatest importance.

There is also this fact to be taken into consideration, that there are influences which actually counteract the effect of increasing scarcity in raising the initial cost. The accompaniments of that intensified exploitation which results in depletion are the constant broadening of the fishing grounds, the inclusion of more than one species of fish and of inferior quality in the catch of the boats, the development of means of preservation, the constant improvement of gear and the increase in quantity of apparatus. All these things tend to eliminate the great and sudden fluctuations in amount of yield which are characteristic of fisheries confined to one species or one locality. These variations in yield render the exploitation of the fisheries expensive and uncertain because the periods of abundance must be made to pay interest upon the capital and to maintain the organization during periods of scarcity. Their elimination as a result of intense fishing undoubtedly does reduce the cost of fish to the consumer, perhaps to the extent that for a while the influence of depletion in raising the initial cost will not be felt.

But in the end that very fact may defeat the natural safeguard which should protect a species, namely, the lack of profit in carrying on a fishery when it comes dangerously near to exhaustion. It becomes possible to prolong a fishery because other species are taken; the by-product becomes the mainstay of the business and the depleted species is kept under a strain for which it could not itself pay. If it were not for cod, perhaps the halibut fishery of Iceland might have long since collapsed; and if it were not for the cheaper round fishes, the flat fishes in the North Sea might be pursued far less rigorously. On the Pacific coast, the tuna and sardine

fishery of California may have been of considerable assistance to the albacore fishery. In fact. the objection often raised to the possibility of over-fishing that the fisheries are prospering and that they would immediately cease to prosper should depletion occur is not a valid one. But that they would ultimately fail as a result of over-fishing seems sure.

Another basis for scepticism as to the reality of the fact of possible exhaustion has been the seeming boundlessness of the sea and its resources. But every fisherman knows that the areas within which fish of a given species are found are very limited, perhaps less so in the cases of "pelagic" fishes than in those of "demersal," yet highly limited nevertheless. And the scientist will testify to the sharp limitations which temperature, depth, salinity and currents place upon every species, so that it is in reality only a very small part of the ocean which yields our commercial fishes. They are, in fact, limited largely to the area of the coastal regions or the continental shelf, where there is drainage from the land, and to comparatively small parts of that shelf. In so far as this productive area is concerned, Gran and others have remarked that it corresponds in general with the distribution of the minute plankton organisms which are vastly more abundant where coastal water is found; and upon these plankton organisms fish must necessarily exist in the final analysis. And even where conditions are thus favorable, and the fisheries are highly developed, as in the North Sea, Allen ("Food from the Sea," 1917) estimates that an acre yields but fifteen pounds of fish per year while pasture land yields seventy-three pounds of beef. In accordance with these facts the experiments which have been made in marking fish and observing the frequency of recapture have shown that the fishermen are able to take, and do take, a very high percentage of the bottom fish in the North Sea. What they do with other fish, such as the herring and the sardine, or in any other regions, is for the most part unknown. It is therefore a mistake to assume that the resources of the sea are inexhaustible, or that over-fishing characterizes small areas easily replenished from without.

There is, indeed, no manner of gauging in advance the productivity of the ocean, in so far as edible fish are concerned. It is in the first place obvious to students of the matter that the amount of food present for fishes does not determine abundance, any more than the amount of grass did determine the abundance of the buffalo on our plains, or of deer in our forests. But it is certain that the rate of reproduction varies widely, and with it the relative resistance to depletion of the species of fish. Such matters as egg production, length of life, varying mortality at different stages and time of sexual maturity must all be taken into account, together

with the sharp limitations provided by climatic and geographical conditions. Moreover, the relative amount of competition for the available food is unknown, although we do know that the commercial fishes are probably but a small part of the population to be supported by the sea. And even if the abundance of the species were a gauge to its resistance to a strain—which it does not necessarily have to be—there is thus far no method of accurately ascertaining the abundance of any one species of fish or of all together save within limited areas of the ocean. It seems, indeed, that there is no method of measuring the amount of fishing a species will stand save by submitting it to a strain.

The only hint which can be obtained concerning the limits of the fisheries in California come from a comparison of the productive area with that of the North Sea, where the bottom fisheries show decline. It is, however, very hard to define the productive area, save by the width of the continental shelf. The area within the one hundred fathom line in the North Sea is approximately 130,000 squares miles (nautical), while off the coast of California it is about 7,500 square miles. In the former case this area is about 300 miles wide and 450 long, but in California the average width is but 8.4 miles, much of this rocky or unsuitable for bottom fishes. In this connection it must be recollected that, as cited above, Gran and other authorities regard the presence of coastal water with land drainage in it as essential to the production of abundant planktonic life. Such water is abundant off the coast of Europe, but the California coast is more arid in nature, especially the southern portion. However, the great fisheries of California are of the "pelagic" type, regarding which such speculation may be limited in value. Nevertheless, it is probably safe to say, when all is taken into consideration, that these fisheries are far more limited in proportion to length of coast line than is the case in the North Sea, and hence much more susceptible to overfishing.

As has been said above, the possibility and actuality of overfishing have been definitely proved, yet it seems true that there is no arbitrary limit which can be economically assigned to any fishery. It would be indeed sheer waste to impose a limit below what might be safely taken and the alternative is plain, to allow the imposition of all the strain the species will carry. It is, as a matter of fact, the only politically practical course of action, at the same time being the correct one from the scientific standpoint.

But it must not be forgotten that the acceptance of such a fact implies the serious duty of close observation and prompt action, in case of overfishing, by the government in control. That is

clearly recognized by the fishery authorities of California and is the mainspring of their actions.

These things having been recognized as true, it followed that a careful survey of measures necessary for such observations was in order, and this has been made in so far as possible. For such purposes the great mass of literature published by the various countries around the North Sea was available, especially that issued by the "Conseil Permanent International pour l'Exploration de la Mer," or inspired by it. It soon became evident that it was impossible for the State of California to undertake the many lines of general inquiry into the varying conditions of the sea and its life which had been investigated more or less by these European countries. That would have been tunnelling the mountain by removing it in its entirety. It was necessary for the state to limit its efforts to those fields which had been shown to bear directly on the ascertainment of the condition of the fisheries; namely, the measurement of the variance in abundance of the fishes in the sea, the effects of fishing upon it and the biological criteria of overfishing. A careful perusal of much of the hydrographic and planktonic work demonstrated its remoteness from the work in hand despite its undoubtedly great ultimate value, and showed that most of the immediate questions could be solved to the required degree without their aid. There were necessary certain biological studies upon the fishes themselves, but above all a statistical study of the fisheries and the fish.

This method of approach, as Johan Hjort has most appropriately said of a certain phase of it, is regarding the study of the fisheries in a similar light to the study of the vital statistics of mankind. It involves primarily the taking of what amounts to a comparative census from year to year in order to test the relative abundance—not the actual abundance—of fish; then to determine whether such great fluctuations as appear are due to natural causes or to overfishing.

For this program, the legislature of the state has passed laws taxing the fisheries industries fifty cents per ton of raw fish used for canning, and has definitely specified the duty of the agents of the state. It is unnecessary to give the details of these laws, but something as to their operation will be of use.

Every commercial transaction involving the first sale of fish is accompanied by the giving of a receipt by the buyer upon a form issued by the fish and game commission and of this receipt one copy is returned to the commission and another kept by the dealer. There are, therefore, actual records of all fish taken for profit, according to the boat and to the day. This unique system has been most successful in its operation for the last three years, avoiding

what we now know were widely erroneous estimates in statistics; while the fresh fish dealer has frequently for the first time a record of his own dealings. The results obtained have continuity, and are in such detail that market conditions, changes in apparatus or fishing fleets, etc., may be readily discounted. So every commercial fishing boat becomes in effect a means of testing the abundance of fish, and it is possible to segregate the effects of scarcity of fish from the effects of those economic changes which alter the total yield. This appears the necessary procedure from the experience of investigators in the North Sea, and is preferable to the limited experimental fishing which is possible. We do, in fact, feel confident that we will have a relatively accurate and sensitive record of the variations in abundance of fish in the ocean, when studied in connection with biological facts.

This scientific collection of statistics is the starting point and the foundation for further investigations. The interpretation of the evidence drawn therefrom is the duty of the biologists engaged by the commission; for the great fluctuations in abundance of fish which may be shown must be analyzed and their true nature discovered. Such natural fluctuations are very likely to be mistaken for depletion from overfishing; or, perhaps, if of opposite trend, as a contradiction of any theory of overfishing when they are in truth, as we have said, due to natural causes, and depletion may exist despite the temporary obliteration of the evidence. There must, as a consequence, be developed and utilized those biological criteria which distinguish depletion due to excessive fishing. The biological knowledge necessary for the use and formulation of such criteria includes among other things the determination of age, the discovery of migrations and in so far as possible the correlation of abundance with natural physical conditions. One may justifiably call it ecology on a vast scale. Granted a fair knowledge of these criteria, it is not exceeding the reasonable to hope that the fishery authorities will be able to give warning when depletion is occurring—and, indeed, unless a degree of confidence can be placed in the competency of the work, the exploitation of the fisheries should not be allowed to proceed freely, nor can freedom be had from the constant fear of ruthless exploitation.

There is, in addition, a need on the part of legislators for competent data upon which measures of regulation may be based. The imposition of arbitrary and reckless restrictions should be prevented by the acquisition of proper knowledge as soon as possible. At present many of our fishery laws are untenable from a scientific standpoint, save in so far as they actually operate to reduce the take. And even if it be said that legislatures will not take proper action, it would be a defeatist's attitude to take to

fail to provide them proper knowledge upon which they might take action. There are a great many legislators who will act along the line of their best knowledge, and more who will respond to intelligent pressure on the part of the public.

In thus accepting conservation as a major policy because of its dependence upon the legal powers of the state, the program adopted in California has not been oblivious of the fact that the work for that purpose has a very definite bearing upon some of the greatest problems of exploitation. As an example, the abundance of fish is subject to great natural fluctuations beyond the control of man. The return from the fisheries vary greatly from day to day, from season to season, and from year to year. The resultant waste is an exaggerated case of the same kind which the electrical engineer meets when he is faced with the "peak load" or maximum use of electricity during a short period each day. Just as apparatus must be available to carry this "peak load," so must the fish canners or dealers maintain the machinery and organization for brief periods of maximum supply and longer ones of scarcity as well as variations in demand which are disconcerting both to the dealers and consumers. The meat packers, their rivals, need not do this. The understanding of these fluctuations so that regularly recurring ones may be expected, others foretold and provision made to meet or avoid them, is without doubt one of the most neglected functions of government scientists. The proper study of depletion necessitates just such an understanding of these changes as will serve the industry.

It must be acknowledged that in adopting such a program, installing such a system of statistics and founding a California state fisheries laboratory at San Pedro to care for the biological science of the subject, the state of California is experimenting. It still remains to be seen whether popular support will be rendered the project, either on the part of scientific men or the general public. The field seems to be one in which the scientist, particularly the biologist, should welcome a chance to show how his work can be applied to the needs of humanity; but, aside from this, basic principles of animal life and behavior are really involved to such an extent as to satisfy the most academic of men and are attacked with the aid of vast masses of material unobtainable through any other source than the commercial fisheries. On the part of the public, it would seem that only a failure to understand or lack of faith in the competency of the work could lead to lack of support.

It is sincerely to be hoped that this effort to approach the problems of conservation upon a rational and well-balanced basis will meet with the reception its sincerity deserves.

DE ANOPLURIS

By Professor G. F. FERRIS
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THE distinguished professor had attained some portion of his distinction by reason of years of work spent upon a small and little studied group of insects. His wife and small daughter chanced into his laboratory one day and discovered a student examining one of these insects through a microscope. The small daughter demanded a look and then came the inevitable question, "What is that?"

"That," said the unsophisticated student, "is a louse."

There was a moment of pained silence and then came the gentle but unmistakable rebuke from the professor's wife, "We always call them Anoplura."

Now these very insects are the subject of my present discourse and lest I again offend the delicate sensibilities of any one I have disguised my intentions by a title to which not even the most fastidious should be able to take exception. To be sure it means the same thing as something else that might have been used, but after all there *is* something in the name by which a thing is called. Even the scratching soldier, from whom one would least expect any delicacy in such matters, conceals the identity of these insects under the euphemistic titles of "seam squirrels" and "cooties." That the deference thus accorded them reduces in the slightest degree the frequency or the painfulness of their attentions may be doubted, but at least the victim is enabled thereby to retain a bit more of the shreds of his self-respect.

In fact under the name of "cooties" these insects may quite properly become a subject even of parlor conversation. The word carries a faintly humorous connotation. One may without risk of immediate social ostracism speak of the great wads of hair that girls wear over their ears as "cootie coops." True, such an expression might not be looked upon with favor in the most refined circles, but we need only reflect upon what would happen were the wording changed a bit to see what a concession has been gained for it to be used at all.

It is perhaps a fortunate thing that this has happened, for even entomologists, who should have put all squeamishness behind them, have been more or less reticent in speaking of these particular

insects. The remark of an author writing in 1842 that "in the progress of this work, however, the author has had to contend with repeated rebukes from his fellows for entering upon the illustration of a tribe of insects whose very name was sufficient to create feelings of disgust" might almost be justified to-day. In fact, in a rather recent entomological book it is said that "from their habits lice are not popular insects even for entomologists to take up," and certainly the amount of attention they have received has never been large.

Yet I confess to being a student of these insects and I do so without hesitation and without apologies. Not to me are they merely "disgusting parasites." Not to me is the term "louse man," with which my botanical and chemical and even entomological acquaintances, with a misguided sense of humor, see fit to address me, a term of reproach. For, know you, there are very few who can merit it, scarcely more than half a dozen men in all the world in fact. To us it is a title of distinction, an evidence that we few have been able to avoid the well-beaten paths of the butterfly and beetle hunters and strike out into a but little explored country. For us it is a country of much interest and—dare I say it?—even of some beauty. And it is my hope that in these pages I may lead others to see in these disgusting parasites, these cooties, some of the things that we, their devotees, are able to see.

For a proper understanding of these parasites, these lice, as I shall not hesitate henceforth to call them, it should be explained that there are really two quite different sorts of them. One sort, known as the bird lice or the biting lice, is found chiefly on birds, although there are a few species on mammals, while all the species of the other sort, the sucking lice, occur on mammals. There is a very great difference in the manner by which the species of these two groups obtain their food. The biting lice feed by biting off and chewing up bits of hair or feathers or skin scales while the sucking lice feed by inserting their beaks through the skin and sucking up the blood of their host. Such a difference in habit is a very important thing, for with it is most intimately bound up the matter of the potentialities of the insects for harm to the animal upon which they live.

It is now a firmly established and generally recognized fact that many of the most important diseases of man and of other animals as well are transmitted by insects. In by far the majority of cases the insects concerned are forms that live upon blood, that actually pierce the skin of the animal upon which they feed. Thus in feeding upon successive individuals these insects may transfer disease-producing organisms from one individual to another. This poten-

tiality for evil is inherent in every blood-sucking form, and its possibilities are realized to a high degree in those blood-sucking lice that live upon man, the familiar "cooties" of the war period.

Under the conditions that usually prevail in armies it is impossible for soldiers to keep themselves free from these insects. Thus it was that certain diseases which are transmitted by the lice became especially prevalent during the late war. Typhus and trench fever are transmitted by lice, and as far as known only by lice, and the measures for the control of these diseases were directed chiefly against their insect carriers. The tremendous losses due to these diseases undoubtedly had a profound effect upon the fighting strength of the various armies. Who can say to what extent the course of the war may have been influenced by them?

There are a few other diseases of man that are known to be carried by lice, and they have been suspected of carrying several others. It is known also that an epidemic disease of certain small Asiatic rodents is transmitted by the sucking louse that occurs upon these animals, and it is highly probable that there are many other cases of the same sort.

On the other hand the biting lice, although far exceeding the sucking lice in numbers of species, are not known to be the carriers of any diseases. If they are abundant upon their host they may cause injury merely by the irritation of their crawling about or by the matting of the hairs or feathers to which their eggs are glued. Otherwise they are of no concern to their host.

But however important and interesting this connection of lice with the transmission of disease may be it is not the only thing about them that is worthy of consideration. This connection with disease is simply a fact, and after all facts are not always as interesting as theories, even though they may be more important. Any one should be able to travel the plain and open road of fact, but there is more pleasure in the narrow and devious trail of theory that occasionally takes the traveler up into the high places—and threatens always to lead him into a bog from which the utmost of mental agility may not be sufficient to extricate him! The most interesting thing about lice is not these highly important facts of hygiene. It is that they may be made to yield a contribution to biological theory.

The starting point of this contribution is the fact that by far the majority of all the different species of lice, both of the biting and sucking groups, are found upon a single species of animal or at the most upon a few very closely related species. It is a curious fact that although horses and cattle and sheep have for many hundreds of years been in close contact in their stables each has re-

tained its particular kinds of lice. There are at least four species of lice upon domestic cattle, but these do not occur upon horses or sheep. There are at least three kinds upon sheep, but none of these has been taken from horses or cattle. There are at least two kinds on horses, but neither of these has been taken from cattle or sheep.

These instances may be paralleled by many others. The inference is obvious. It is evident that under normal conditions each species of louse "prefers" to feed upon a particular kind of animal. In other words it is adapted to feed upon the blood or epidermal structures of this particular host and does not find the blood or the epidermal structures of another kind of host a suitable food. Furthermore these insects are very reluctant to leave their host and even after its death may be found clinging to the hairs or feathers. Under experimental conditions lice have been fed upon animals very different from those upon which they normally live, and it is true that sometimes under natural conditions they may be found upon an animal on which they do not belong. Still this does not change the fact that usually each species of louse sticks pretty closely to a certain kind of animal, passing from one individual to another in the nest or at mating time. Thus it is that the parasites are in a way inherited by the young from their parents—heirlooms, if I may be pardoned an atrocious pun.

The next fact of interest is that the same species of louse may be found upon distinct but closely related species of birds or mammals in widely separated parts of the world. Thus we have upon the kingfisher in North America a louse that is the same as one on a kingfisher in Egypt. Another species is found upon various species of hawks throughout the world. Another is found on seals in both the Pacific and Atlantic Oceans. Another is found on ground squirrels in Siberia and in North America.

Now all these animals are so widely separated that certainly it is impossible for the louse of the African kingfisher to transfer directly to the North American kingfisher or for the louse of the Atlantic seal to transfer directly to the Pacific seal or for a transfer to take place in any one of the many other cases of this sort that might be mentioned. Then how has the parasite managed to get upon both of its widely separated hosts?

There are enough facts of this character to demand some attempt at a logical explanation. There must be a reason for them. If we remember that these parasites are normally passed down from one generation to another as a sort of racial inheritance and if we follow far enough the train of reasoning that is thus initiated we can not but conclude that at some time this African kingfisher

and the North American kingfisher, or the North American ground squirrel and the Siberian ground squirrel, or the members of any such pairs as we may name, were together as a single species. We have a set of facts that can not reasonably be explained unless we accept the theory of evolution. The conclusion is inevitable that at some time these kingfishers, or whatever they may be, had a common ancestor and that the shifting of land masses or climates or some other cause has left part of the descendants in one corner of the world and some in another and that there by various evolutionary processes they have become sufficiently different to be recognizable as different species.

One of the most remarkable examples of the working out of such a change is that of the llama and the camel. The paleontologists tell us that at one time there were many more species of camels and camel-like animals than there are now and that these animals first appeared in the New World. At the present time, however, the only remaining representatives of this group are the llamas of South America and the camels of Asia and Africa. Yet, separated by half the world—these cousins, or forty-second cousins, still show their relationship and their common ancestry not only in their bodily structure but in their parasites as well, for on both there is found the same species of louse.

We can extend the list of facts much farther and still the answer of common ancestry is the only reasonable explanation of them. The louse of the domestic hog has its nearest relative in the bush pigs of Africa. The lice of one kind of squirrel are more closely related to those of other squirrels than they are to the lice of other animals. The lice of the domestic chicken have their nearest relatives in the many different species of lice upon the other chicken-like birds.

Like nearly all theories, however, this one must allow for certain exceptions. We can lay down a general rule but it is almost too much to expect it to work always, at least if we are dealing with such things as living organisms. It is one of the difficulties in the way of the study of living things that they refuse to stay put. They simply will not go always into the little pigeon holes that we block out for them. Like men they must at times assert their individuality by breaking our trifling little laws; they at times demand the right of living their own lives in their own way. In some instances related species of lice are found upon animals that are certainly not very closely related and sometimes different species of lice are found on animals that really ought to have the same kind. So it must simply be admitted that in some cases other influences have been at work. Still the broad facts remain as I have pictured them.

All this leads finally and directly to the question, "What about the lice of man?" And here the evolutionist may rub his hands together in satisfaction. For here—in the most interesting place of all—the theory works! The lice of man do indeed find their nearest relatives in the lice of the apes and monkeys. In fact, it is even possible that lice of some of the apes are really the same species that occurs on man. Nor can the argument that here we are probably dealing with one of those exceptions that I have mentioned hold, for the facts throughout are entirely too consistent with each other.

So the evolutionist who, heedless of the fair name of his species, would derive man from some ape-like ancestor finds here another bit of support for his theories. He finds another stone for the defending wall that piece by piece has been built about them. Nor will this wall, like the walls of Jericho, crumble before the blasts of its enemies' trumpets. Not even before the most silver tongued of them.

I would like to close this with a moral, but morals have gone out of fashion and then it is obvious enough, anyway.

TOPOGRAPHICAL MAPS OF THE UNITED STATES

By Professor WILLIAM MORRIS DAVIS
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THE United States Geological Survey is still engaged in preparing a topographic map of our country. Progress thus far made is summarized on a large two-sheet map of the United States, on a scale of 1:240,000 or 40 miles to an inch, which serves as an index for all the quadrangles surveyed and published up to 1921; but, as a matter of fact, there are large areas in certain western states which are here marked off as surveyed, but which are represented only by maps published nearly 40 years ago, on so small a scale and of such inferior workmanship that their areas must soon be surveyed again more worthily. The contrast between the vague, sketchy contours of those early maps and the minutely intricate and apparently accurate contours of the newer maps marks the advance in topographic standards during the interval of nearly half a century.

But Americans as a rule are still topographically uneducated. They are accustomed to "flat" maps, on which the form of the land surface, the "relief" as it is technically called, is either not represented at all, or else so badly represented that it might better remain unrepresented. Automobilists are coming to know something of the ascents and descents on the roads that they follow; but most of them are still so inexperienced in or distracted from the observation of the landscape that they do not look at it closely or attentively; and even if they do, they hardly see what they look at. The driver of a car of course should not be expected to turn his attention far to the right or left; but his fellow travellers may do so, and they would be greatly aided in seeing the country they traverse by carrying along the topographic maps of their route. The cost of the maps is very low; an inquiry addressed to the director of the U. S. Geological Survey at Washington will bring information concerning maps published for any desired part of the country.

If distance lends enchantment to some views, appreciation lends enjoyment to many others, and appreciations of landscape views is greatly increased by the possession of a good map. As examples

of the contrasts between different parts of the country, look at the map of the Brasua Lake quadrangle, next west of Moosehead lake in Maine, where the brooks, many of them called "streams," have a well-defined flow only in their steep descents from the uplands, while in the lower lands they are for the most part either delayed in swamps or stopped in lakes; or of the Williamsport quadrangle, Pennsylvania, where the drainage is so well developed that neither lake nor swamp is to be found, and where the single or double ridges, running in the zigzag pattern of the Alleghenies, prevail with occasional enclosed limestone valleys, of which Nippenose is a perfect type; or of the Rives Junction quadrangle, Michigan, where the surface is agitated in the minute inequalities of morainic topography with many kettles and ponds; or of the Craig quadrangle, Missouri-Nebraska, where the boundary between the state of Missouri and Nebraska follows a former course of the Missouri river, which has now changed its channel to the right or left, thus inconveniently leaving patches of each state on the wrong side of the river; or of the Natchez quadrangle, where the uplands east of the Mississippi are cut into a labyrinth of intricately branching ravines as they fall off to the broad flood plain in which the great river swings in large meanders; or of La Sal Vieja quadrangle on the coastal plain of Texas, where the smooth surface has no valleys and very few hills, but is pitted by countless depressions, small and large, holding wet or dry lakes. The variety of topography is infinite; the lover of mountain and valley, of forest and stream will find no end of enjoyment in striving to apprehend its many expressions.

None of the maps are more remarkable than those which represent the slopes of the great volcanic island of Hawaii. Several of these have already been published, and four more soon to be completed are now issued as "advance sheets, subject to correction," on a scale of 1:31,680 with 10-foot contours incompletely drawn. Two of these sheets include parts of the Kau Forest Reserve and a stretch of the Volcano Road that leads from Hilo on the east coast southwestward to the cauldron of Kilauea. All these sheets reveal admirably the long continuity of the gradual slope by which the volcano descends from its great height, the minute ravines incised with sub-parallel courses down the slope, the occasional ragged lava surfaces where the contours are given a minutely serrate pattern, the occasional oblique or radial scarps which seem to indicate fractures and displacements in the huge mass, and most striking of all a vast bulging or convex slope, skirted around its southeastern base by the Volcano Road, which contradicts the general idea that volcanic slopes are concave. If these sheets are

continued so that, when mounted together, they may include a large share of the island, they will afford an unequaled illustration of volcanic topography on a large scale.

One of the several ways in which the newer maps are improved over the earlier ones is in the addition of submarine contours, with the same vertical intervals as those on the land, for quadrangles on the ocean and lake coasts. Thus the Cape San Martin quadrangle, California, shows the bold slopes of the Santa Lucia range, which descends to the Pacific with crowded 50-foot contour lines, to be adjoined by a gently inclined sea-floor plain with wide-spaced 50-foot contour lines across a breadth of from two to four miles off shore, before a moderate slope to deeper water begins. In strong contrast therewith, the Portsmouth quadrangle shows the sea bottom off the coast of New Hampshire and Maine to be almost as undulating as the land, although, perhaps because soundings are scattered, the texture of the submarine undulations is drawn in a coarser pattern than that of the terrestrial surface. The manifest reason for the contrast between these samples of Pacific and Atlantic borders is that the shallow sea bottom along the California coast has been uninterruptedly subjected to normal marine agencies —waves and currents—by which land-derived detritus is smoothly distributed; while the sea bottom near the New England coast has been recently, as the earth counts time, subjected to glaciation.

Another novelty on the recent maps is the addition of the numbers and subdivisions of the rectangles, over 900 in all, into which the whole country has been divided by the War Department. These rectangles measure one degree of latitude on the sides and one degree of longitude at the top and bottom; they are numbered from north to south in successive columns, beginning on the Pacific coast. Each rectangle is divided into north and south halves; and each half into four quarters (I, northwest; II, northeast; III, southwest; IV, southeast). Thus the Conejos, Colo., quadrangle of the Geological Survey nomenclature, on a scale of 1:96,000, is the 298-S-II & IV quadrangle of the War Department. When the scale is large, the numerical nomenclature is somewhat unhandy; thus the Firebaugh, Calif., quadrangle of the Survey on a scale of 1:31,680, is the 60-N-II-W/2-SW/4 quadrangle of the War Department.

Outline maps of the states have been called for and prepared in recent years on a scale of 1:500,000. All are now completed, except that Nevada, Utah, Colorado and New Mexico are in press, and Texas is yet to be drawn. These maps will doubtless be issued eventually with contours, but for the present the map of such a state as South Dakota shows only its rivers and streams, many of

which are printed in broken lines to show their intermittent flow, its railroads, its county and village names, and its township and section rectangles as marked off years ago by the Land-Survey preliminary to selling the public lands. Many of our state maps in the central and western parts of the country are based on those crude surveys, which served their purpose well enough when they were honestly made in plain country, but in rough country the case was different. One of the recently issued Geological Survey maps of a quadrangle in a mountainous state explains in a legend at the bottom of the sheet that the township and sectional rectangles of the Land Survey for a part of the area are omitted "because land plats and topography can not be reconciled and no [section] corners can be found." This recalls a story of early days in California, told by the late Professor Brewer of Yale, who was in the 60's a member of the California Geological Survey. A desperado, at last captured after many deeds of violence, was about to be hanged by a vigilance committee. When asked if he had anything on his mind which he wished to confess, he said he had; but it was not his manifold murders that troubled him. The only misdeeds to which he owned up with remorse had been committed while he was an assistant on the Land Survey; the law required that the corners of the square-mile sections should be marked with wooden posts, charred at one end and driven into the ground; the desperado confessed that, in a district where wood was scarce, he had marked the section corners with burnt matches. We are only about half-a-century climb up from that rung in the ladder of our civilization. One of the most characteristic signs of our ascent to a higher level is the preparation of a large number of excellent maps of our domain, some examples of which are noted above.

WHAT NEXT IN IMMIGRATION LEGISLATION ?

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The Imperative Necessity of Further "Permanent" Legislation

THE present 3 per cent. immigration restriction law will expire on June 30, 1924. What shall take its place? The conditions which led to its adoption will still exist. We are facing a permanent tendency toward rapidly increasing and steadily deteriorating immigration, and millions of prospective immigrants overseas are impatiently waiting for the thirtieth of June, 1924, when they will rush in, in a seething chaotic mob, unless Congress takes steps to stop them.

The Opposition to Restriction

To any program for restriction there is certain to be active, well-organized and heavily financed opposition. This opposition is centered in (1) certain racial groups which are interested, not in the future of America, but in the increase of their own race in America; (2) employers who want foreign labor so cheap that it is dear at any price; who put pocketbook above patriotism; (3) the steamship companies, who believe themselves to have vested rights in the United States as a dumping-ground for their human cargoes, and (4) those who have been well termed "the incurable sentimentalists." Every effort is now being made to misconstrue our present laws; to distort and misrepresent their effects; to make them unworkable and unpopular. These laws are being subjected to organized attack by "interested" individuals, alien racial groups and hyphenated societies, and certain influential newspapers which carry heavy steamship advertising. *All of these are bent on making any restriction whatever appear unreasonable, unjust and inhumane.* It is very important that the character, the motives and the tactics of this opposition should be known.

Our General Immigration Law must be maintained and enforced

There can be no question that our general immigration law of 1917 must be maintained. This law names some thirty classes of

aliens who are excludable on mental, physical, moral or economic grounds. These include the insane, the idiot and the feeble-minded; those who have loathsome or dangerous contagious diseases; criminals; prostitutes; persons physically incapacitated from earning a living, illiterates, etc. In fact the enumeration of the undesirable classes is so complete that, if the law had been and were always rigidly enforced, our immigration "problem" would give us far less trouble than it does. Our law bars criminals, but our court and institution records show a large excess of foreign-born. Our law bars the insane, but our insane hospitals, especially in the northeastern States, are filled with aliens. Our law bars those suffering from loathsome and dangerous contagious diseases, and those suffering from physical disability that may affect ability to earn a living, but political "pull" often suffices to admit over the doctor's certificate, against the express provision for exclusion. Our law debars paupers; yet an insignificant number of aliens is debarred on these grounds, although the majority of those now arriving come without money, and are not productive laborers.

In a recent paper on the deportation system of several States, Dr. H. H. Laughlin, of the Eugenics Record Office, Cold Spring Harbor, N. Y., brought together some startling facts.

> A recent survey shows that in 1916 the several states expended on an average of 17.3 per cent. of their total governmental expenditures in maintaining custodial and charitable institutions. This percentage varied from 5.4 in Alabama to 30.5 in Massachusetts A survey of 460 state institutions for the several types of the socially inadequate, with a total of 210,835 inmates, recently (1922) completed by the Committee on Immigration and Naturalization of the House of Representatives, found 21.14 per cent. of these fifth of a million inmates to be of foreign birth and 44.09 per cent. to be of foreign stock—that is, of foreign birth or who have at least one parent foreign born. Thus if, on the average, it costs the same in the institutions to maintain native-born and foreign-born inmates, then currently the several states are expending approximately 7.62 per cent of their total revenues in caring for degenerate and dependent human foreign stock. This is the logical outgrowth of the asylum idea which has pervaded the American immigration policy.

The proper enforcement of our general immigration law involves not only a very careful and deliberate scrutiny of all arriving aliens, but also a systematic and thorough round-up of all aliens already in this country who are deportable because they have become public charges, or who have been found to belong to certain other specified classes of undesirables which are by law subject to deportation. Never yet since the law of 1917 has been on our statute books has it been strictly enforced. It is to the credit of the present administration that a distinct improvement in

this respect was made during the past year. And it should be remembered that strict enforcement leads to a certain extent to self-enforcement, for the more aliens are debarred as undesirable, the fewer such attempt to get in.

THE PERCENTAGE LIMITATION MUST BE MADE PERMANENT

The present 3 per cent. law is not perfect, but it has on the whole worked successfully, and has fully justified its enactment. It is reasonably generous in permitting the reuniting of families; in allowing unrestricted entry to tourists and other excepted classes, and it has kept our ports open to a fairly considerable inflow of newcomers, for it should be remembered that it permits an annual immigration of over 350,000. It has undoubtedly worked hardships in some cases, but most of the newspaper stories of such hardships have either been intentionally exaggerated, or have been untrue. Public sympathy is easily aroused by a single instance of real or fictitious hardship. The far more vital problem of how the present character of immigration is to affect the American race of the future is more remote, and attracts less attention. The administration of the law is fortunately in the hands of officials who are enforcing it with justice and humanity.

There is one point in connection with the 3 per cent. law which is often lost sight of. For a good many years before the war, aliens from southern and eastern Europe largely outnumbered those from northern and western Europe. Under the new law these numbers are nearly equalized, so that if all nationalities fill their allotted quotas, the so-called "newer" immigration can not contribute more than about one half of our annual inflow. This fact is biologically of great significance. In the fiscal year ending June 30, 1922, deducting emigrants from immigrants, we gained in Nordic stock, and lost in the natives of southern and eastern Europe.

Those who attribute solely to the present percentage restriction the need of labor in certain industries are either wholly ignorant of the facts, or are intentionally trying to mislead the public in the effort to break down all restrictions and to flood the country with cheap labor. In this connection it should be realized that (1) there has been a very considerable emigration of alien labor during the recent period of business depression and unemployment; (2) if all countries filled up their quotas, which they have not been doing during the past year, there would be an annual inflow of over 350,000; (3) the countries of northern Europe have fallen much farther below the quotas than those of southern and eastern Europe, most of the latter having exhausted their quotas, thus showing that the intelligent and skilled labor of northern Europe

has not been disposed to emigrate to the United States; (4) the immigration of aliens who are natives of any countries of the New World is not subject to the provisions of the law; (5) a considerable proportion of our immigration under the 3 per cent. law has been made up of sweat-shop workers, peddlers and small shop-keepers, not of strong, sturdy, intelligent laborers. This is clearly not the fault of the law, but results from the present tendencies of immigration. Thus the "need of labor" is by no means to be attributed solely, or even largely, to the percentage law. Furthermore, there is little doubt that northern and western Europe will fill up its quotas during the coming year, as immigration from those countries is increasing. The relation of immigration restriction to the rising scale of wages was so clearly stated by Honorable Albert Johnson during the closing days of the session of Congress recently ended that we can not do better than to quote from his remarks on this point.

> Every good American sympathizes with workingmen in their effort to obtain decent wages and decent conditions. . . . Restriction is an absolutely necessary supplement to a protective tariff. Immigration must be curtailed until all workers, native and foreign-born, whether in the basic or other industries, get wages and have conditions commensurate with American standards and ideals if we are to maintain those standards, ideals, and, in fact, our very civilization. Just as soon as wages in those industries rise to the point where the breadwinner can rear and support his family in keeping with American standards, the native-born will reinvade those industries from which they have been driven by the ruinous competition of imported cheap labor, often inducted into conditions amounting to slavery, and when wages do rise to that level the native supply will quite meet the demand, just as native labor does in every other country.

This is the situation in a nut-shell.

As a result of the awakening on the part of our people to the effects of the practically unrestricted new immigration from southern and eastern Europe and Asia, for the first time, and against bitter opposition, the principle of numerical limitation has been established by overwhelming majorities in Congress in a manner which gives equal treatment to all the nationalities which make up our population as far as is consistent with the maintenance of what we know as America. This principle, which has been long and strongly advocated by leading authorities on immigration, should be made our permanent immigration policy. Our own country, foreign countries, the steamship companies—all have become more or less adjusted to a definite numerical limitation of our alien immigrants. The machinery is in operation, and works remarkably smoothly, as much so as any restrictive legislation ever works. In reenacting a percentage law, whether it be the present 3 per cent., or the 2 per cent. which has been suggested in certain

bills lately introduced into Congress; and whether the percentage quotas be based on the census of 1910 or an earlier census, it would be wise to make the law somewhat more elastic. Reasonable provision should be made to prevent the breaking up of families. This could readily be accomplished by treating the *immediate* members of a family as a unit whenever some members could be admitted without exceeding the quota while the remaining ones would otherwise be excluded because exceeding the quota. Exceptions in favor of bona-fide tourists, of students and of professional classes are necessary. Further, a maximum number of 500 or 600 could wisely be set for the admissible aliens from certain countries whose quotas are very small under the 3 per cent. provision, and from which we receive highly desirable immigrants. The quota from Australia, for example, in the present fiscal year is only 279 and that from New Zealand and Pacific Islands is only 80. With these changes, a percentage law such as the present one would involve very few hardships. At the same time if the exceptions were carefully drawn, there would be no danger of our being swamped by any such flood of aliens as swept in upon us before the war, and as will, in even greater volume come in again unless we take steps to prevent it.

It can not be too strongly emphasized that, while the original argument in favor of the 3 per cent. law was economic, the real, fundamental, lasting reason for its continuance is biological. This side of the matter was so clearly and forcibly presented in an editorial note in the October number of the *World's Work* that we can not do better than to quote that statement here:

> If America is to realize its fullest possibilities, it must exercise the principle of selection. Up to the present time it has ignored this method Our policy of opening our gates to all comers has really meant that we have recognized no distinctions among peoples, that we have refused to admit that one presented better material for citizenship than another, and that we have pinned our faith on the existence of some wonder-working alchemy in the American atmosphere which could transmute an inferior race into a superior one. But the teaching of all history, as well as the experiments of the biological laboratory, show the absurdity of any such easy-going philosophy, and the nation has reached the point where it should base its future upon scientific and historical fact.
>
> This is really the argument in favor of the three per cent. immigration law. It does not directly apply this principle of selection, it is true; that is, it does not in so many words limit immigration in future to particular races and particular nations. Yet indirectly it does accomplish a result which is not dissimilar. It takes the population of 1910 as representing the proportions of different peoples which, under the practical limitations of the problem, may be regarded as furnishing the desirable racial composition of the future United States. The great majority of that population came from the countries of northwestern Europe—Germany, Scandinavia, Great Britain and Ireland. There are few who have studied the matter who do not regard these

peoples as the most desirable elements with which to construct the nation. By limiting future arrivals to three per cent. of these stocks, therefore, the law does provide that the American people of the future, as well as of the present, shall be chiefly from the races of northwestern Europe. That is the reason why this law, or one based upon the same principles, should represent the permanent policy of the republic.

Objections to a Flat Numerical Limitation without Proper Selection

The sole purpose of such a numerical limitation as that embodied in the present 3 per cent. law is to cut down numbers. Because immigration was largely of an undesirable quality we cut it down. The 3 per cent. law certainly does let in a smaller amount of bad stock, but does not improve the stock, physically, mentally or morally. It doubtless shuts out some highly desirable immigrants because the quotas are mostly filled with undesirable ones. Furthermore, being based on nationality, *i. e.*, country of birth, and not on race, it has made possible a disproportionate immigration of Jews to the exclusion of thousands of non-Jewish aliens. This fact comes about because of the extraordinary activities of Jewish relief societies, both in this country and in Europe. These organizations take all the steps necessary to enable their co-religionists in Europe to emigrate to the United States, such as procuring their passports, purchasing their passage tickets, and caring for them *en route* to the ports of embarkation. Thus the annual quotas from several European countries are largely filled with Jews. In this way the "flat" percentage restriction has been worked with injustice to non-Jewish aliens who desire to come to the United States.

It is because a flat percentage restriction works only quantitatively and not qualitatively that it is absolutely necessary to maintain and to enforce our general immigration law of 1917, as urged above.

Overseas Inspection of Prospective Immigrants is not practicable

There seems to be so many and such obvious advantages, both to the prospective immigrant and to the United States, in having some sort of examination overseas, that there is at present a widespread demand for such inspection. This is no new agitation. It has marked the history of immigration literature and debate for at least thirty-five years. Such foreign inspection would seem to be our only way of looking into the antecedents, habits and character of our intending immigrants; of picking out those who by heredity and education are best fitted to become American citizens; of eliminating, at the source, all those who, under our general immi-

gration law, are physically, mentally, morally or economically undesirable. Overseas inspection suggests itself as a humane method of stopping most of the inadmissible aliens before they start on their voyage, and it should be welcomed by the steamship companies, for it would mean that few rejected aliens would have to be taken back at the companies' expense.

The plan recently most widely advocated is that the United States should establish an immigration office in each consulate to function in connection with the work of viséing passports, the immigration inspectors to certify as to an alien's admissibility to this country before his passport is viséd.

On its face this plan seems sensible, wise and humane. It seems to offer a simple and practical solution of the immigration problem. Yet there are so many objections to it, and so many obstacles in the way of its accomplishment, that for years all committees of Congress which have considered it, as well as the Immigration Commission of a decade or so ago, and leading authorities on immigration, have been forced to abandon it. A first objection to overseas inspection is that it would necessitate a very large increase in the number of immigration inspectors and medical officers, with the resulting heavy expense. If an undesirable alien is to be stopped before he leaves home and if the antecedents and character of our prospective immigrants are to be accurately ascertained, we must have our inspectors and doctors at all the thousands of places all over Europe and western Asia from which our immigrants come. For it is obvious that a United States immigration inspector at a consulate in Hamburg, *e. g.*, making an examination there of, say, a thousand Jews coming from all parts of Poland, would be no better able to determine their eligibility there than on their arrival at Ellis Island. Of course, those who might be declared inadmissible by the inspector at a European port, or at some inland city where we have a consulate, would be saved the voyage across the Atlantic, but complete information concerning any alien could only be obtained in his home town or hamlet. In the second place, overseas inspection would divide the responsibility between the officials abroad and those at our own ports, for there is no question that we must, under any and all conditions, always maintain our inspection service at our ports. In all doubtful cases, each inspector, the one abroad and the one here, would throw the responsibility upon the other. Thirdly, overseas inspection, supplemented by home inspection, would work hardship on the aliens because it would never be certain that all with overseas certificates would be allowed to land on a second examination here.

Lastly, whenever overseas inspection of prospective immigrants has been seriously considered by Congress, certain foreign govern-

ments have objected to it on the ground that this country would thereby be assuming extra-territorial sovereignty not in accordance with treaty rights. Delicate diplomatic problems are here involved. No scheme for foreign inspection could be devised which did not use the existing machinery of consular offices. As the Honorable Albert Johnson has recently said, "Our consular offices are established under authority of trade and commercial treaties, each of which sets forth specifically what functions may be carried on by consular employees. Examination of persons who contemplate migration to the United States is not included. It follows that if we are to set up a plan for examination of immigrants overseas we must of necessity revise many of our trade and commercial treaties." This is the situation in which the United States finds itself in this matter of overseas inspection.

It is obvious that the interests of the United States and those of foreign countries are absolutely opposed in this matter of immigration selection. We want the sound, able-bodied, intelligent. We do not want the defective, the delinquent, the physically unfit. The former are the ones most desired at home. The latter, foreign governments would not regret to have emigrate. It is, therefore, readily understood why these governments may not be too ready to acquiesce in any new arrangement whereby we can select the best and refuse the worst of their people. The present passport and visé system gives foreign governments the power to designate and to allow to emigrate those persons only whose presence in their own countries is not desired. The selection of our future citizens is therefore not in our own hands.

In spite of the present obstacles in the way of our establishing overseas inspection, it might perhaps be possible, through ordinary diplomatic channels, without the necessity and the delays of negotiating any new treaties, to come to an amicable working agreement—a Gentlemen's Agreement, in short—with the governments of foreign countries from which our immigrants come, whereby, by international cooperation, the United States could make some sort of a preliminary examination of intending immigrants before they sail. If the present administration could bring about such an agreement, it would take a long step in the settlement of this most difficult and important national problem. The sympathetic attitude of the present Secretary of Labor on this question has been clearly indicated. Thus, in an address given in Boston on June 14 last, he said (*The Boston Herald*, June 15) "We must bar out those who menace our national life and our national institutions. Much could be done by providing for inspection of prospective immigrants in Europe before they undertake the long journey

across the Atlantic. I would insist upon the most rigid tests of blood, physical, mental and moral stamina before admitting a single immigrant." With this view all patriotic and thinking Americans must surely agree.

Overseas inspection, however, desirable as it would be, should not and could not in any way replace the other restrictive and selective measures advocated in the foregoing discussion. We imperatively need a stricter enforcement of our general immigration law, and a permanent percentage limitation with the amendments above suggested.

ADDENDUM: If we want the American race to continue to be predominantly Anglo-Saxon-Germanic, of the same stock as that which originally settled the United States, wrote our Constitution, and established our democratic institutions; if we want our future immigration to be chiefly made up of kindred peoples from northern and western Europe, easily assimilable, literate, of a high grade of intelligence, able to understand, appreciate and intelligently support our form of government, then the simplest way to accomplish this purpose is to base the percentage limitation upon an earlier census than that of 1910, *i. e.*, before southern and eastern Europe had become the controlling element in our immigration. In an important discussion of "The Immigration Problem," in *Scribner's Magazine* for September, 1922, which came to the present writer's attention after he had completed the foregoing article, Professor Roy L. Garis, of Vanderbilt University, suggested that our permanent legislation be based upon the percentage principle, but that we admit 3 per cent. of the different nationalities of foreign-born in the United States as shown by the census of 1890. This, as Dr. Garis rightly says, "is a simple yet practical solution, based on historical facts." If instead of 3 per cent. we should admit 5 per cent. of the foreign-born resident here in 1890, the annual total for all Europe would be 400,000, in round numbers. Of these, about 200,000 would be admissible from northwestern Europe; 50,000 from Scandinavian Europe; 165,000 from Central Europe; 10,000 from eastern Europe; 10,000 from southwestern Europe, and 2,000 from southeastern Europe. Such a law would result in bringing in a large preponderance of immigrants who present no difficulties of assimilation; who do not give rise to our immigration "problem." It would thus be automatically selective, as well as numerically restrictive. If we are to maintain the physical and mental standards of our race; if we are to make America safe for democracy, to keep America for Americans, there is no more logical or practical method than this.

A MODERN MECCA

By Professor A. E. KENNELLY

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THE ancient Arabian city of Mecca is in one sense the most remarkable in the world. It is the birthplace of Mahomed, the *Resoul 'Illah*, or prophet of God, and it contains the Kaaba, or central shrine of the Mahomedan faith. No giaour may enter there. Very few Christians have ever seen the place. The explorer Burton, for instance, one of the most famous oriental linguists, penetrated there, under elaborate disguise, at the risk of his life.

Over two hundred millions of persons—about one eighth of the population of the globe, or nearly double the population of the United States—are reputed Mahomedans. The great majority of these Mahomedans are devout worshippers, according to the ritual of the *Koran*. Several times a day, notably at dawn and sunset, the faithful, scattered over Asiatic and African lands, unfold their prayer-carpets, lay them in the assumed direction of Mecca, and prostrate themselves thereon in prayer. This custom of diurnal obsequience towards the prophet's holy city has continued for centuries with very little change. Mecca has thus maintained a marvellous hold upon the daily thoughts and acts of a vast number of human beings. In their psychology, the Kaaba is the common and universal point of reference. Their lives are lived in perpetual procession towards that one place. Every year, about one hundred thousand pilgrims of zeal journey from afar to visit it. He who has thus attained to the holy city acquires with pride the title of *Hajji*, which entitles the owner to social respect.

Although the modern world has created no new Mecca in any such sense as Mahomedanism conveys, yet in a certain very remarkable way it has created a scientific Mecca at Sèvres, in the beautiful park of St. Cloud, on the Seine, near Paris, and close to the famous old Sèvres porcelain factory. Here, on a plot of land which France has given to the world, by extraditing it from French boundaries, is an unpretentious building, called the "*Bureau International des Poids et Mesures,*" especially constructed in 1875, for enabling accurate measurements of standard lengths and weights to be carried on quietly, and at a nearly uniform temperature, within its walls. Eight meters beneath the surface of its courtyard is a vault containing a closed steel safe, wherein are treasured the

world's most valued reference standards of length and weight—the international meter and kilogram—together with certain "*témoins*" or ancillary duplicates. The building is mainly devoted to comparisons between these fundamental standards and the corresponding replica of other nations, through the medium of working copies. It has no upper stories and is surrounded by the forest park. Fortunately for the even tenor of its duties, it ordinarily escapes attention from the ubiquitous tourist, despite its proximity to the much visited porcelain museum. Neither Baedeker nor "Guide Bleu" refers to it, and it finds no place on the list of objects to attract the interest of the visitor; yet it may properly be described as a latter-day temple for the guardianship of the "Lares and Penates" in the world of weights and measures. The expense of its upkeep is shared, in definitely prescribed proportions, among the twenty-eight foremost countries of the world.

The need for an international clearing house and depositary for the world's standard meter becomes evident from a consideration of industrial needs alone, as well as from a cursory glance at the history of the subject.

If a steel bar, say one yard in length, is ordered, without any further specifications, from a smithy, we might reasonably expect the bar to be delivered true to length within one per cent., more or less; that is to a precision of one part in 100, or 10^2. This may be described as a precision of the second order. It does not mean that the smithy could not furnish a higher degree of precision in length, if the need existed; but merely that in the ordinary course of business, a yard bar at the smithy might well be interpreted to include bars longer or shorter than a yard by as much as one per cent. Moreover, the measurement of the bar, by the act of laying a yard-stick alongside it, would be an operation lasting only a few moments. Nevertheless, if the tolerance of something more than one per cent. were clearly admitted, the moral certainty of the measure within those limits would be very great. Any intelligent man receiving the bar from the smithy, and laying a creditable yard-stick beside it, could see at a glance that the two were nearly alike in length; so that unless some question as to the amount of tolerance were raised, he would feel a high degree of assurance that—in the common use of language—the bar was a yard long.

The rough bar from the smithy might next be sent to a machine shop with an order that it be trimmed, smoothed and cut to a finished length of say 35 inches; but without any specifications as to tolerance in precise length. In the operations of smoothing and finishing, the mechanic entrusted with the order, would probably

spend a little time in adjusting its length to "35 inches." One per cent. he would regard as unworkmanlike, and he would probably aim at a precision say of one per mil; *i. e.*, one part in 10^3, or of the third order. If he were put upon his mettle, he might be willing to attempt a precision of the fourth order, or 1 in 10^4; but the extra time involved in such an effort might not be justifiable. Even to reach the third order, he would have to make the length correct within 0.035 inch, and much more time would be needed in the measurement than was spent at the smithy in attaining the second order. In the first place, an ordinary rough yardstick would no longer suffice. A graduated steel tape or straight edge would be necessary. Moreover, the operation of juxtaposition and reading off the length would take much longer than before. Finally, in spite of this increased mental and physical care in the task of measurement, the degree of moral certitude as to the reliability of the result will probably not have increased proportionately. In repeating the measurement, the mechanic will begin to arrive at slightly different results and the effect of the discrepancies disconcerts the judgment. Of course, unless the mechanic made a gross error or mistake in reading the tape, he would feel convinced that the finished bar was much nearer to "35 inches" than one per cent.; but upon the new plane of third- order precision engaging his attention, he might feel less assurance of success than his predecessor, who measured only to the second order of precision at the smithy.

If now the finished 35-inch bar were sent to a superior workshop, to be assembled perhaps in some fine piece of mechanism, after being adjusted to say 34.8 inches, at a room temperature of 20° Centigrade, with a tolerance of 0.004 inch, this would entail refinishing the ends of the bar and measuring its new length to one part in 10^4, or to fourth order precision. For the purpose of making this measurement, a special gauge might have to be prepared. If the bar in the assembled mechanism had to be made interchangeable with similar bars coming from other machine shops, the gauge might have to be adjusted to a precision of the fifth order in length, at a special workshop for the construction of precise gauges. In order to reach fifth order precision in the gauge at the special workshop, a standard measuring rule of yet higher precision would be needed there. It would not be unreasonable to require a precision of the 5½th order in that special workshop standard. That standard would probably be compared and calibrated against a still finer standard at the Bureau of Standards in Washington, where a precision of the 6.5th order, or one per 3,000,000 might be readily obtainable. Finally, to keep the stand-

ards of the different national laboratories of the world in mutual agreement, an international standard is maintained at Sèvres, where the precision attainable is of the seventh order.

It is clear that every measure of length, either in the world of business or in the world of science, has its order of precision, over the entire range from the first to the seventh, depending upon its construction and purpose. No one expects a higher order of precision than the particular purpose of the measure in question demands; because the effort and expense involved in securing an extra order of precision is relatively great. There are certain lines of industry, notably in gauge making for fine tools, where fifth order precision is necessary. Not many decades ago, this was the highest order scientifically attainable in measures of length. The advance from the fifth to sixth order demanded an immense amount of scientific and industrial effort. Progress had to be made in the mathematics of accidental errors, in metallurgical chemistry to provide improved materials, in physics to learn the laws of length variation in material standards, in tools, to fashion the improved parts, in workmanship and experience to handle the new tools. At the present date, we can look for the seventh order precision in the comparison of the various national meters with the international meter at Sèvres; but although this suffices for practically all industrial needs, it is inadequate for certain scientific requirements. Certain problems of the Einstein theory, for instance, might find solution, if the eighth or ninth order of precision in the measurement of length were attainable.

If material civilization advances, we may hope to secure one higher order of length precision at Sèvres in the course of another century. This would probably add one order to national scientific length measurement all over the globe. Apart from questions of moral or spiritual development, an estimate of the world's civilization might be furnished, based upon the order of precision realizable in the certificates of meter-bar comparisons furnished by the bureau at Sèvres.

The permanence and inviolability of the international meter are clearly of importance to all nations. The control of the Sèvres bureau has been vested, since 1875, in an international body composed of delegates from the twenty-eight leading national governments that are parties to the bureau's maintenance. The international meter and kilogram are deposited at the bureau in such a manner that seven successive keys have to be used in order to reach them. Three of these keys are in regular service for the doors of the building; but the four others belong to the special vault in which the standards are preserved, and are placed in the

custody of as many different officers of the international committee. Some of these officers live abroad; so that the keys are usually kept far apart. It has thus only been possible to open the vault at the regular six-year meetings, when the assembling officers produce their respective keys. The inconvenience of so inflexible a *modus operandi* manifested itself during the world war. At the outbreak of the war, one of the officers, entrusted with a key, resided in Germany. That key, being in an enemy country, was inaccessible. If Sèvres had been subjected to bombardment, it would have been necessary to remove the standard meter and kilogram to a place of safety, and this would have involved breaking into the vault. In order to provide against such a contingency in future, a new set of regulations has been brought into effect; whereby a duplicate of each vault key is deposited with the Institut de France, and so that, under special emergency, the vault can be opened by its authority.

One of these six-year meetings of the International Conference took place recently in Paris under the presidence of M. Emile Picard, the permanent secretary of the French Academy of Sciences. On October 6th, 1921, the delegates met at Sèvres and at a specified hour formed themselves into a visiting and attesting committee, under the leadership of M. Ch. Ed. Guillaume, the Director of the Bureau.

The committee members line up across the courtyard in column by twos. At the signal, the procession enters the main and east door of the Bureau, and passes along a corridor, in the half light, to a descending stone stairway. Incandescent lamps light up, and we descend to a basement floor. Again, down another stone stairway, to a sub-basement. At this level, the temperature changes but little all the year round. We now face the first of the three steel vault doors in the east wall. It opens to the corresponding official key. Behind it are two other steel doors, which are successively unlocked, revealing the vault beyond. This is about 4 meters long in an easterly direction, 3 meters wide and three high. An electric incandescent lamp, that has been idle for eight years, is turned on and we can see the interior clearly. The walls and ceiling are lined with white enamelled brick. Opposite to the entrance against the eastern wall is a table supporting a steel safe. There is nothing else in the vault except an auxiliary table against the north wall. The director produces the last of the seven keys and unlocks the safe. Its doors swing open and disclose two shelves. On the upper shelf are three meter-bar cases, a minimum-maximum thermometer and a hygrometer. On the lower shelf is a row of five glass double bell-jars. Inside of each is a shin-

ing cylindrical standard kilogram. The director calls for a reading of the instruments, which have been shut up in the safe since 1913. The min-max, thermometer register 10.6°—13.2° Centigrade, or a total range of only 2.6 degrees during those eight years. The hygrometer shows 88 per cent. humidity. The director calls attention to the international meter and kilogram, with their control duplicates. He carefully lifts out of the safe the central case, containing the primary standard or prototype meter, and lays it on the auxiliary table. He opens the case and reveals the brightly gleaming meter bar within. Like all the other standard bars, its section is of a special X shape, so designed as to offer the maximum stiffness, or resistance to sagging in the middle, when the bar is supported at its two ends. Of course, a stout platinum-iridium bar, a little more than forty inches long, and built with any reasonable shape of cross-section, would sag very little at the center when the bar is supported at its ends. Nevertheless an extremely small sag would be apt to alter, in perceptible degree, the apparent length of the bar, as measured on its surface. By giving this X shape to the section, and cutting a flat strip of surface at the middle of the groove in the X, the meter length is marked off along this flat strip, where the change in length due to any possible central sag becomes quite negligible. The meter bar is not graduated, or marked off into equal divisions like an ordinary rule. There is merely a fine scratch cut with a diamond point across the bar near each end. The international meter is defined as the distance between these two fine line scratches, when the bar is at the temperature of melting ice.

No hand touches the bar, which lies face down in its case. It is the final reference standard, and does not need to be used except as a final arbiter, in case differences should arise among the working standards. Its duty is merely to remain steadfast—to preserve its dimensions unchanged.

Only a few of the witnesses can occupy the vault at one time, and the air in it becomes oppressive. As soon as those within have recognized the contents of the safe, they leave the vault and make room for others.

In about half an hour, the standards are replaced on their shelves, the safe is shut and locked, the light is turned off and the vault doors closed. The world's standards of length and weight thus resume their wonted repose, until the next awakening by a visiting committee, probably six years hence. This visiting committee, however, returns to daylight and reforms in the courtyard, where it is photographed by a moving-picture machine, to record the passage of its members.

The measurement laboratories of the Bureau are also visited by the committee. These laboratories have specially constructed walls, to keep the temperature within them nearly uniform. In one of them, standard meter bars are compared and certified. The bar to be tested is laid horizontally on end supports in a tray of water, alongside of the working standard of the laboratory, whose error with respect to the international meter of the vault has been carefully determined. Being composed of platinum-iridium, the bars do not tarnish under water; although they have to be cleansed from deposits of dust or organic matter—of which more anon. The immersion of the bars in water is desirable during the tests, in order to enable their temperature to be more closely determined, each bar being only true to length at a certain temperature, and correction being necessary for observed deviation of temperature from the standard.

A microscope is supported on a stone pillar over each end of the bar, in such a manner that the cross-hair of the eyepiece can be brought over the delicate line marks on the ends of each bar in turn, the operations being regularly repeated many times according to a definite schedule. The observations, as finally collected and reduced, reveal the difference between the length of the tested bar and that of the working standard. Readings can be taken to the eighth order, or to 0.01 micron (10^{-8} meter, about 1/2,500,000th inch; but the final result is only depended upon to the nearest 0.1 micron, or ten-millionth of a meter, a precision of the seventh order. The micron is the one-millionth of a meter, and is the unit of length in practically universal use among scientific workers with the microscope, all the world over.

Some excitement was recently aroused at the Bureau, by the discovery that two working standard meter bars, in use there during many years, although retaining their lengths almost unchanged with respect to each other, had both lengthened in that time by about 0.4 micron, or 1/65,000th of an inch, the change of length being progressive. After much search, it is believed that this minute lengthening of each bar has been gradually brought about through the constantly repeated cleansing of the polished working surface by the gentle rubbing of a cloth. The rubbing had always been directed, as a matter of habit, along the bar towards the end. In this way, it is supposed that the walls of the fine diamond scratch across the bar, near each end, were slowly pushed over and away from the middle of the bar, by 0.2 micron, in the course of long usage. It has since become the prescribed routine to clean the surface of a meter bar by rubs delivered alternately in opposite directions.

Another laboratory is devoted to the measurement of standard weights. In each corner of this room a delicate balance weighing machine is mounted, while the observer sits in the middle of the room at a distance of four meters from each and all of them. The reason for his having to sit so far from his work is that if he were to take up a position comfortably close to the balance he operated, the warmth from his body would probably vitiate the measurements seriously for the degree of precision aimed at, in spite of the usual windows and shields with which such a balance is ordinarily provided. His respectful distance from the subject of his investigation suggests the old rhyme:

"Who suppes with ye Deville
Shoulde have a longe spoone."

With the aid of an ingenious arrangement of four parallel and horizontal brass rods, running from the balance to the observer, and which he can rotate in different ways, he is able to weigh the test kilogram mass against the mass of a standard kilogram, on the scales four meters off, and to read the balance through a telescope. One of these four-rod combinations enables him to observe the difference of weight between say the tested mass on the left-hand scale, and the standard mass on the right-hand scale; then to clamp the beam, next to lift off the two weights and reverse their relative positions, bringing the tested mass to the right and the standard mass to the left; and finally to repeat the weighing in this reversed relation, all at four meters' distance.

A standard kilogram is a solid cylinder of polished platinum-iridium, with its circular edges slightly rounded. The mass of such a cylinder can be measured, after making all corrections, to the nearest hundredth of a milligram; or to the 10^{-8} kilogram—a precision of the eighth order. It is curious that the available precision of mass determination should thus be one order greater than that available in length determination in our national standards, at this period of the world's history.

It is evident that a blow, or severe mechanical shock, administered to any standard meter bar, might readily alter its length and render its use unreliable. Great care has to be taken in the national laboratories of the various countries not to let a standard meter bar fall. Occasionally, a national standard meter bar is brought back to Sèvres from some distant part of the world for recomparison at the Bureau. In such a case, it is always entrusted to a careful messenger, and usually the chief of the national laboratory takes it himself. At last October's Paris meeting two national meter bars came back for retesting, one from Washington, D. C., and the other from Japan. In each case, the director of the

national laboratory brought it in person. In the American instance, Dr. Stratton brought the meter bar from the Bureau of Standards at Washington, with the aid of an assistant. The special case containing this meter always remained in the care of one or the other, being carried from place to place with more care than a mother ordinarily devotes to the handling of her baby. A tumble that might not hurt a baby might injure a meter bar. In the Japanese instance, Dr. Tanakadate arrived at Sèvres, after a journey from half way round the world, carrying his meter case in his arms. The way in which the precious national standard was carried in each instance brings to mind the story of the Italian knight, the founder of the well-known Pazzi family, who, in one of the crusades, returning from Jerusalem on horseback, always sat backwards, or facing the tail of his horse, because he tended constantly a little fire in a brazier, whose embers he had first lighted from the sacred fire in Jerusalem. Journeying painfully and slowly, he was determined to bring the fire still alive to his native Italian city. His unusual gait and attitude naturally aroused much astonishment on the journey, and the name "pazzo," or crazy, clung, so the story goes, to him and his family thereafter.

The reason for so much care being warranted, moreover, in the American instance was that both by act of Congress and by executive order, the U. S. Yard is defined and maintained as a certain definite fraction of the international meter, as is also the U. S. pound avoirdupois as another definite fraction of the international kilogram. Consequently, all American measures are linked with the fundamental units at Sèvres. Although the Washington Bureau of Standards has more than one official copy of the meter; yet it is advantageous to have one of the copies checked and recompared at "Mecca" from time to time.

After the international bureau at Sèvres was organized in 1875, and set to work making and certifying copies of the international meter and kilogram, 30 standard meter bars in platinum-iridium were finished and approved by 1889. The bar which agreed most closely with the pre-existing standard meter of the "Archives" was adopted as the "international meter" for deposit in the vault, and the others were distributed by lot among the various contributing governments. Meter-bars Nos. 21 and 27 fell to the share of America, as well as Kilograms Nos. 4 and 20. The work of measuring and intercomparing the 30 standard bars, previous to their acceptance and distribution by the international committee, took over three years to accomplish.

Meter No. 27 and kilogram No. 20 were brought to Washington, under seal, by an officer of the U. S. Coast and Geodetic Survey,

and delivered to President Harrison at the White House on January 2nd, 1890. President Harrison, after breaking the seals and opening the cases himself, signed for their receipt and certified to the reception in good order of these national standards. These exercises were conducted with befitting ceremony, a special reception, followed by a social function and dance, being arranged at the White House for the occasion.

As originally planned, the meter was decimally derived from the dimensions of our universal mother earth, so as to be the ten-millionth of the distance from the North Pole to the Equator, on a meridian carried through Paris. In this way, if the meter should become lost or entangled in dispute, it might be re-established by geodesy. It would not, of course, be necessary to start with a tape-line from the north pole. It would fortunately suffice to measure the length of a portion or portions of an arc of the meridian, between terrestrial stations whose difference in latitude should be determined with the requisite degree of precision by astronomical methods. A series of meridian measurements were actually conducted about the year 1799, for the purpose of arriving at the length of the standard meter, although the best scientific instruments available at that date were distinctly inferior to those now in regular use. A marked advantage of this decimalized meridian basis for the meter is that with decimalized angles, which are slowly but surely winning their way to favor through ease in their calculation, the kilometer, or ten-thousandth of the earth quadrant, becomes the nautical as well as the terrestrial mile, thus bringing both land and sea under the dominion of the same standards. Recent measurements have shown that the actual standard meter is a little short of the theoretical meridian meter. With respect to the meridian through Paris, the standard meter is stated to be approximately 0.2 millimeter, or 200 microns, too short. This error is insignificant and negligible from the standpoint of sailor's charts, or navigational requirements; but it is an enormous error from the standpoint of national standard intercomparison at Sèvres. By the time that the shortcomings of the standard meter with respect to the theoretical meter became known, it was too late to change the standard. Moreover, supposing that the standard meter of to-day were corrected to the best known value of the theoretical meter; there can be no doubt that in the course of another century of progress in geodesy, the meter-bar thus corrected would have to undergo a new correction at that date, probably much less than the 200 microns now known; but yet very large with respect to inter-comparison work. The result would be that we should never have a final meter, and we should always

have to examine into the date of a meter-bar in order to be able to use it with a high degree of precision. For practical purposes, therefore, the world has been compelled to accept a standard meter whose precision with respect to the theoretically decimalized meridian is only of the 3.5th order, in order to secure a precision of the 7th order in replication and dissemination. In any case, the probable precision of redetermination by astronomical measures is at present much less than that attainable by direct meter-bar comparison. Consequently, if the standard meter should be lost in any one part of the world, it could always be re-established by reference to the international meter at Sèvres.

Will it always be necessary to make periodical comparisons between national meter-bars and the international standards at Sèvres? Perhaps not. Already a method has been developed, which, with the aid of the Michelson interferometer, enables the number of waves of cadmium red light to be counted in the length of one meter. This number has been stated to be 1,553,164.1, optically measurable with a precision of the seventh order, or practically the same as that of direct mechanical comparison. It may, therefore, be found, after sufficient experience has been acquired, that instead of sending a standard bar from Washington to Sèvres for calibration and certificate, it may only be necessary to use, in the Washington laboratory, the right kind of cadmium light, and to count off the right number of its wave lengths—a number exceeding a million and a half—in order to arrive at the length of one international meter, to the requisite degree of precision. Moreover, it is possible that yet another method may be found for deriving the meter locally, without making a pilgrimage to "Mecca" for it. At present, however, it is necessary to make the pilgrimage.

If then, we examine to-day any scale, divided rule, or measure of length, we always, either consciously or unconsciously, look towards Sèvres. The rule has always been marked off and graduated by comparison with a standard, and usually this standard has been more precise than the copy. If the graduated rule is very rough and imperfect, with a correspondingly low order of precision, we do not have to go far to find a possible standard of reproduction for it; but the finer and more nearly accurate the rule, the higher up in the scale of development we must search for a possible progenitor. The very finest in any country are only obtainable by direct comparison with the national standards. These, in turn, have been derived from Sèvres. Thus there is always a lineal succession of standards of length and of mass to every local inch, foot-rule or pound standard that is worthy of the name.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service

REWARDS FOR WORKING INSIDE THE ATOM

Two Englishmen, one Dane and one German, are the winners of Nobel prizes in physics and chemistry for 1921 and 1922. The names just announced from Stockholm are Albert Einstein, of Berlin; Neils Bohr, of Copenhagen; Frederick Soddy, of Oxford, and Francis William Aston, of Cambridge. This is a striking illustration of the unity of science in spite of national divisions, for these four scientists have been in unconsidered cooperation trying to solve the same question, the most fundamental problem of the universe, what is the atom made of.

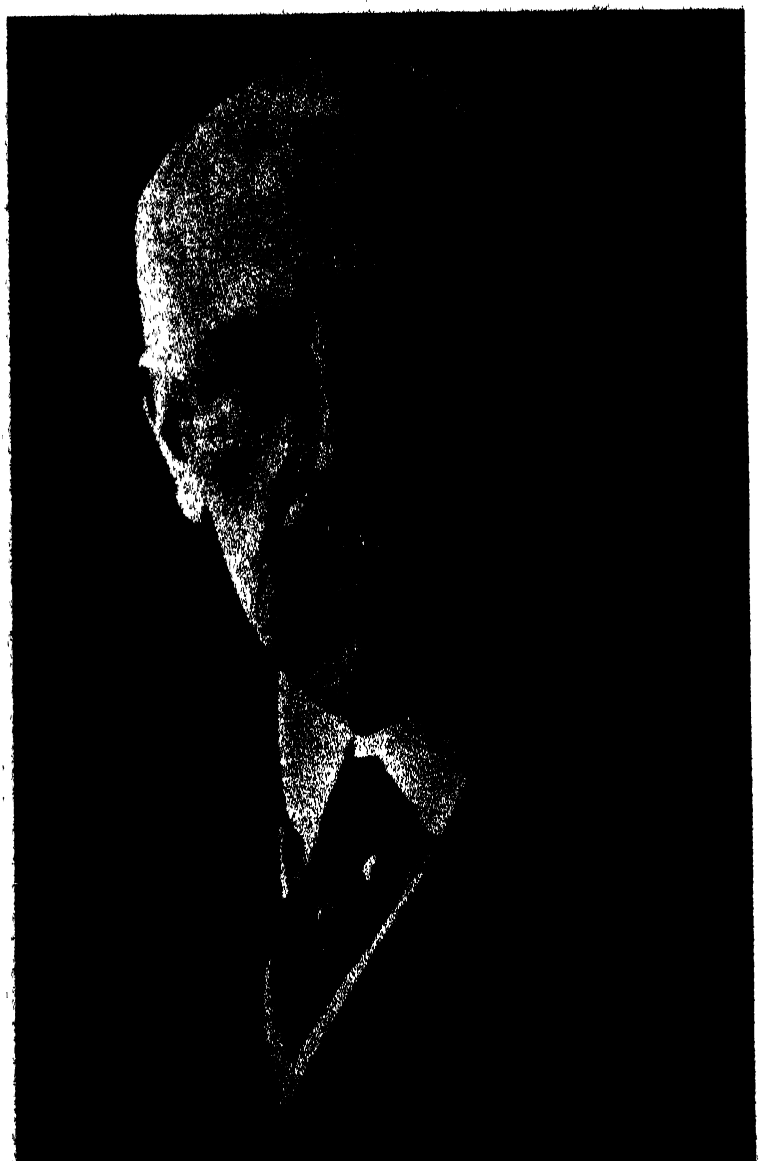
The atom was originally supposed to be the smallest thing possible, the ultimate unit of the universe. The ancient Greeks, who were the first to think about the question, concluded that if you kept on cutting up matter into smaller and smaller pieces you must come at length to something too small to be further sub-divided, so they called this smallest of all possible particles the "atom" which means "uncutable." The modern chemist took over this old Greek idea to serve for the combining weights of the elements and likewise assumed that the atom was the limit.

But early in the present century, Professor J. J. Thomson, of Cambridge, found radioactive matter giving off particles more than a thousand times smaller than the smallest atom, and for this discovery he received the Nobel prize of 1905. This opened up a new field of research that has been prosecuted ever since, especially by British scientists. Professor Soddy has not only done a large part of this work but he has given a good popular account of what it means in his book, "Science and Life."

Chemists used to suppose that all the atoms of the same element were exactly alike in weight and every other way, wherever it came from, but this fixed idea has been upset. Soddy found, for instance, that lead from thorium ores is eleven per cent. heavier in its atomic weight than lead from uranium ores. Soddy named these different forms "isotopes." What are listed in chemical text-books as atomic weights and were supposed to be unvarying turn out to be in many cases averages of several isotopes. Mercury, for instance, which is listed as having an atomic weight of 200.5 consists of six isotopes with weights varying from 197 to 204.

Aston devised an ingenious way of making the atoms record their own atomic weights. He drives a stream of positively chargea particles between the poles of a powerful magnet which deflects them in the degree of their relative weights. When the dividing streams strike a photographic plate they leave their tracks and from these the mass of the various isotopes can be determined. Chlorine has always been a puzzle to chemists because its atomic weight figured 35.46 instead of a whole number. But subjected to the scrutiny of Aston's apparatus it is found to be a mixture of two kinds of chlorine atoms, one weighing exactly 35 and the other exactly 37.

The Scandinavian scientist, Bohr, was the first to venture on a picture of the new fashioned atom. We had



DR. FRIDJOF NANSEN

The distinguished Norwegian Arctic explorer and man of science, who has recently been occupying himself with the relief of sufferers from the Russian famine and is now engaged in similar work in Asia Minor.

been accustomed to think of atoms as round hard balls, but according to Bohr they are more like miniature solar systems with a positive electrical nucleus in the center and one or more negative electrical particles, called "electrons," revolving around it at tremendous speed.

Here is where Einstein comes in, for, while the planets moving majestically in their orbits obey Newton's law of gravitation, the electrons, which travel almost as fast as light, deviate from Newton's law in proportion to their speed and follow the formula of Einstein instead. According to Newton the mass of a body remains the same whatever its motion. According to Einstein, the mass increases with its velocity. The difference between them is inconsiderable for any ordinary speed, but when we are dealing with electrons moving at the rate of 100,000 miles a second it becomes important. The public has associated Einstein exclusively with astronomy because his theory has been tested at a time of eclipse, but the theory of relativity has applications quite as revolutionary and much more practical in earthly chemistry and physics.

HOW THE CHEMIST MOVES THE WORLD

THE chemist provides the motive power of the world, the world of man, not the inanimate globe. Archimedes said he could move the world if he had a long enough lever. The chemist moves the world with molecules. The chemical reactions of the consumption of food and fuel furnish the energy for our muscles and machines. If the chemist can only get control of the electron, he will be in command of unlimited energy. For in this universe of ours power seems to be in inverse ratio to size and the minutest things are mightiest.

When we handle particles smaller than the atom we can get behind the elements and may effect more marvelous transformations than ever. The smaller the building blocks the greater the variety of buildings that can be constructed. The chemistry of the past was a kind of cooking. The chemistry of the future will be more like astronomy; but it will be a new and more useful sort of astronomy, such as an astronomer might employ if he had the power to rearrange the solar system by annexing a new planet from some other system or expediting the condensation of a nebula a thousand times.

The chemist is not merely a manipulator of molecules; he is a manager of mankind. His discoveries and inventions, his economies and creations, often transform the conditions of ordinary life, alter the relations of national power, and shift the currents of thought, but these revolutions are effected so quietly that the chemist does not get the credit for what he accomplishes, and indeed does not usually realize the extent of his sociological influence.

For instance, a great change that has come over the world in recent years and has made conditions so unlike those existing in any previous period that historical precedents have no application to the present problems, is the rapid intercommunication of intelligence. Anything that anybody wants to say can be communicated to anybody who wants to hear it anywhere in all the wide world within a few minutes, or a few days, or at most a few months. In the agencies by which this is accomplished, rapid transit by ship, train or automobile, printing, photography, telegraph, and telephone, wired or wireless, chemistry plays an essential part, although it is so unpretentious a part that it rarely receives recognition. For instance, the expansion of literature and the spread of enlightenment, which put an end to the Dark Ages, is ascribed to the invention of movable type by Gutenberg, or somebody else, at the end of the four-

teenth century. But the credit belongs to the unknown chemist who invented the process of making paper. The ancient Romans stamped their bricks and lead pipes with type, but printing had to wait more than a thousand years for a supply of paper. Movable type is not the essential feature of printing, for most of the printing done nowadays is not from movable type, but from solid lines or pages. We could if necessary do away with type and press altogether, and use some photographic method of composition and reproduction, but we could not do without paper. The invention of wood-pulp paper has done more for the expansion of literature than did the invention of rag paper 600 years ago.

Print is only an imperfect representation of the sound of speech, a particularly imperfect representation in the case of English because we can not tell how half the words sound from their spelling. But the phonograph gives us sounds directly, and the audion and the radio have extended the range of a speaker, until now a speaker may have an audience covering a continent and including generations yet unborn. What these inventions do for sound, photography has done for the sister sense of light. By means of them man is able to transcend the limitations of time and space. He can make himself seen and heard all round the earth and to all future years.

THE COST OF NIAGARA

If a man stood on the banks of the Mississippi at the time of the spring freshet, when the stream was carrying down to the Gulf fences, pigs, chickens, furniture and, occasionally, a house, he would be seriously concerned over the loss of the property of those who had so little to lose, and perhaps exert himself to save some of it; but the continuous calamity of Niagara arouses in him no feelings of a nature to mar his enjoyment. He shows the same æsthetic appreciation of a sublime and beautiful spectacle and the same indifference to its cost as Nero at the burning of Rome.

It is easier to comprehend how much it is costing us to keep up Niagara as a spectacle if we put the waste in concrete terms. Various engineers have estimated that it would be possible to get from Niagara Falls over 5,000,000 more horse-power than is now utilized. In one of the large steam plants of New York City the cost of power is $50 a year per horsepower. Taking these figures as sufficiently close for our purpose the water that goes over the Falls represents the annihilation of potential wealth at the rate of some $250,000,000 a year or nearly $30,000 an hour.

We are told that there are some millions of people in poverty and poorly nourished in this country, yet here is wasted the equivalent of 250,000 loaves of bread an hour. We may see with our mind's eye 600,000 nice fresh eggs dropping over the precipice every hour and making a gigantic omelet in the whirlpool. If calico were continuously pouring from the looms in a stream 4,000 feet wide like Niagara River it would represent the same destruction of property. If a Carnegie Library were held under the spout it would be filled with good books in an hour or two. Or we can imagine a big department store floating down from Lake Erie every day and smashing its varied contents on the rocks 160 feet below. That would be an exceedingly interesting and diverting spectacle, quite as attractive to the crowd as the present, and no more expensive to maintain. Yet some people might object to that on the ground of extravagance who now object to the utilization of the power of the falling water.

It must not be supposed that I am insensible to the beauties of nature or ignore their æsthetic and cultural

value. On the contrary, I would wish to enhance the interest and impressiveness of Niagara Falls by making it a rarer spectacle. The reason why people fail to appreciate the beauty of the clouds, of the sunset and of the landscape from their windows is because these are so common. If a bouquet of fireworks were shot off at eight o'clock every night we would not care to look at them. Of course the Falls would be turned on for all legal holidays and as often as there was sufficient demand for it. On such occasions those who wished to go down the current in barrels could enjoy their favorite sport Weddings would naturally be arranged to come off at a time when the Falls fell At the hours when the water was prohibited from making a run on the banks, rambles over the eroded rocks and worn channels would be of great interest to the geologist and the tourist. Couples and groups could be photographed at the Falls then, as they are now, by posing them in front of a painted screen.

Many more people would see Niagara and their enjoyment of it would be much greater if it could be seen only on fete days. Thinking they could see it any time, thousands of people have neglected it in favor of some passing show.

Of course, there is something impressive in the thought that the flood pours thundering into the abyss all of the time regardless of sight seers. But if one has not sufficient imagination to find an equal emotional value in the contemplation of the varied life and industry it supports as it pours through the penstocks and spins the turbines he can swell with satisfaction on the thought of the thousands of years when it was of no use to anybody.

In 1893, when Lord Kelvin stood on the brink of Niagara, he was not so much impressed by its grandeur as he was saddened by the sight of such an enormous waste of power, and he expressed the hope that he would live to see it all utilized, an observation which was much ridiculed at the time by hard-hearted sentimentalists and unimaginative poets. To them Niagara was a mere spectacle, but to the great scientist, who had devoted his life to the study and exposition of the law of the conservation of energy, it was much more. His prophetic eye could see the poor who might be enriched, the homes that could be made happy, the hungry who might be fed, the naked who might be clothed, and the toiling millions who might be relieved of their burdens by the water dashing upon the rocks below for the amusement of idle tourists.

LOOK OUT FOR ALPHA CENTAURI

As if we did not have enough to worry about, what with winter coming on and coal so short and clothing so high, here comes along Professor Ellsworth Huntington, of Yale, with a book on "Climate Changes" which warns us that the stars in their courses may fight against us. He has a theory that the glacial epochs and the lesser disturbances of the earth's climate are largely due to prior disturbances in the sun's atmosphere and these in turn may be caused by the approach or increased activity of certain stars. All the stars, including our sun, are in radio communication with one another, and when one flares up over something it arouses responsible excitement in all the others within range. Then, too, the stars are not "fixed," as we used to think, but are wandering about in various directions, and when two stars come close enough together they become mutually inflamed by the proximity and may become permanently attached.

Now the nearest star to us is the brightest one in the Centaur constellation, therefore named Alpha Centauri. It is only about 25 trillion

Wide World Photos

THE ASTROPHYSICAL OBSERVATORY BUILT FOR PROFESSOR ALBERT EINSTEIN AT POTSDAM

miles away and its light takes four and a third years to reach us. Alpha Centauri is not only big and bright and relatively near, but it is triple and variable. Its two main components are like two suns the size of ours, revolving around one another every 81.2 years. When they are closest they are 1,100,000,000 miles apart and when their orbits separate most widely they are three times as far as that from each other. It is when the twin stars are nearest that we should expect them to be most active in sending out light waves and electrons. These reaching the sun might set up wild whirlings in the solar atmosphere, which would appear to us as an unusual abundance of sunspots, and would affect the weather on the earth.

The dates when the two bright spheres of Alpha Centauri were nearest together and most radiant are 81.2 years apart and these fall on the years 1388, 1469, 1550, 1631, 1713, 1794, 1875 and 1956. Comparing these with the records of sunspots, which have been kept only for the last century and a half, we see that such evidences of solar disturbances were most evident in periods ending in 1794 and 1875, and that another period of high solar activity started in 1914 and may be expected to end about 1956.

If this theory of stellar influence is true we may expect something to

happen somewhere between 1950 and 1956. What it will be Professor Huntington does not venture to surmise, but he reminds us that in the years preceding 1388, when Alpha Centauri was active, Europe was a very uncomfortable place to live in. There were droughts and floods, famines and freezings The Baltic was frozen so that horse sleighs could cross from Germany to Sweden, and the Danube and the Rhine sometimes inundated the cities on their banks and sometimes nearly dried up.

There are more serious grounds for suspecting Alpha Centauri of a malign influence on the earth for that star was nearest to the earth 28,000 years ago, being then only 3.2 light-years away. Now this is the date that geologists have set for the end of the last Great Ice Age so the approach and proximity of Alpha Centauri may have had something to do with that spell of cold weather which came near freezing out the human race. The world is even yet convalescing from the chills of the Glacial Epoch. Greenland which once was really green with ferns and figs is still covered by an ice cap.

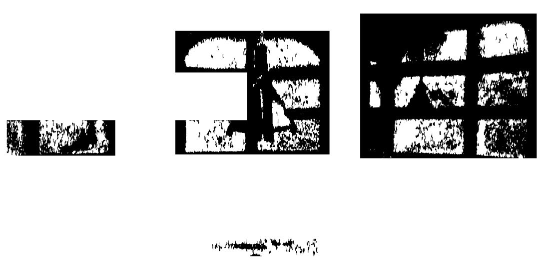
We need not fear another glacial age from the same cause for Alpha Centauri is now 4 3 light-years away and leaving us at the rate of thirteen miles a second. But Sirius is due in this vicinity in 65,000 years and that would be quite as-- I should say, might be equally—bad for us

But Professor Huntington endeavors to console us by reminding us that the human race not only survived several such periods of climatic stress, but has come out of them in each case stronger and better for the struggle for existence He is a firm believer in the value of stormy weather. He is a New Englander.

NEW LIGHT ON THE ORIGIN OF LIFE

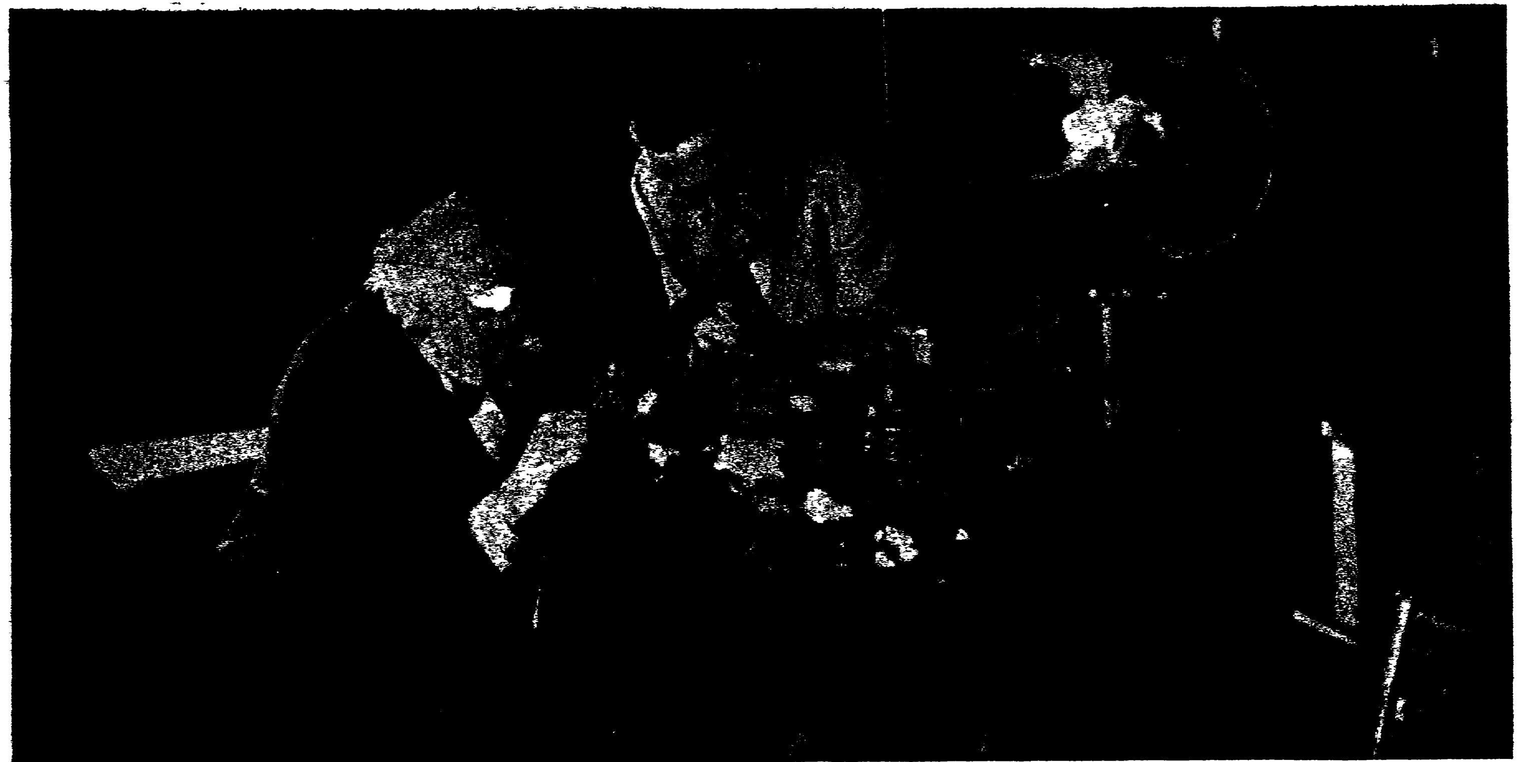
WAS the first living being a plant or animal? How could either originate out of non-existing matter?

These are questions that have hitherto baffled scientists. They could



Wide World Photos

A LABORATORY OF THE ASTROPHYSICAL OBSERVATORY BUILT FOR PROFESSOR EINSTEIN



Wide World Photo

MR. THOMAS A. EDISON AND DR. CHARLES P. STEINMETZ
In the Research Laboratories of the General Electric Company at Schenectady

trace back, more or less satisfactorily, the lines of development of plants and animals to the simplest and most primitive forms of life, but there they ran up against an insurmountable wall, on the near side of which was the world of living organisms and on the far side the world of inert mineral and inorganic matter

We all know that non-living matter can be converted over into living matter for we do that ourselves whenever we eat or breathe We all know that green plants have the power of building up sugar and starch and wood (the so called carbohydrates) out of the water of the soil and carbon dioxide of the air, for we can see them do it any sunny day But it is life only that can bring into the living organism this inorganic material Water and carbon dioxide, plain "soda water," do not spontaneously change over into sugar or start to grow into a plant It requires green colored granules of the leaves, called chlorophyll, to effect this transformation.

But chlorophyll is a very complicated chemical compound. It is formed only by green plants as they develop in the sun's rays from white sprouts. So the plant must exist before chlorophyll is formed. But, on the other hand, a plant could not exist unless it got its energy from the sugar and other stuff stored up previously by some chlorophyll-bearing plant. Even the simplest green plant can not live and grow on its nutritive salts in the sunshine unless it has a bit of plant-stuff to feed on as a starter.

We might surmise as a way out of the dilemma that animal life came first on the earth, and, in decaying, supplied the primitive plants with the necessary organic food stuff. But here we are blocked because animals are parasites of plants. They live on the sugars and so forth that the green leaves have stored up by means of sunshine.

So this was the perplexing situation. Plants can feed on animals or other plants. Animals can feed on plants or other animals But where could the first animals or plants get their food when there was nothing but mineral matter in the world? It was worse than the old question, which came first, the hen or the egg?

But of late we are beginning to get light on the problem The wall between the living and non-living is crumbling Certain sugars and proteins, such as the plant forms that we eat, can now be made in the laboratory out of inorganic material. Artificial cells have been constructed that grow and crawl and feed themselves and stick out feelers and subdivide very much like living cells. It has been found that ultra-violet rays, that is, light of such short waves that it can not be seen, can convert water and carbon dioxide into sugar as chlorophyll does

These short waves are not contained in the sunshine that reaches the earth to-day, but it is found that ordinary rays may act the same way in the presence of certain substances such as iron rust in water These same energetic rays are able to incorporate the nitrogen of mineral salts into compounds like the protein of the living cell. So here we see the possibility that the action of the sunlight on the sea in primordial periods—or even in the present—might produce sufficient food to give a single cell a start in life and enable it to grow and multiply and develop into other and higher forms.

But how this primal cell got to going in this way the biologists are only beginning to surmise. Dr. E. J. Allen, at the recent Hull meeting of the British Association for the Advancement of Science, ventures the theory that the first organism was of the animal sort and spherical shape, but that it gradually grew a tail or whip that enabled it to rise to the sunny surface of the sea whenever it

sank below and that it there acquired the chlorophyll by which it could make its own food out of the air and water. This is far from knowing what did happen in those early days, but it is a great advance to be able even to speculate as to how it might have happened since not many years ago it seemed that it could not happen at all

SCIENTIFIC ITEMS

WE record with regret the death of Robert Wheeler Willson, emeritus professor of astronomy at Harvard University, of Guy Henry Cox, formerly professor of geology at the Missouri School of Mines; of Dr. Chauncey William Waggoner, head of the department of physics in West Virginia University; of F. T. Trouton, emeritus professor of physics in the University of London, and of E. Bergmann, director of the Chemisch Technische Reichsanstalt, Berlin.

THE Henry Jacob Bigelow medal of the Boston Surgical Society was presented to Dr. William W. Keen, of Philadelphia "for conspicuous contributions to the advancement of surgery," on the evening of October 25, when Dr. Keen addressed the society on "Sixty years of surgery, 1862-1922."

ON the occasion of the celebration of the fiftieth anniversary of the Dutch Zoological Society there were admitted as honorary members: Professor O. Abel, Vienna; Professor M. Caullery, Paris; Professor L. Dollo, Brussels; Professor B. Grassi, Rome; Professor V. Häcker, Halle; Professor S. J. Hickson, Manchester; Professor N. Holmgren, Stockholm; Professor T. H. Morgan, New York; Dr. F. Sarasin, Basle, and Dr. J. Schmidt, Copenhagen.

FOSTER HALL, the chemical laboratory of the University of Buffalo, designed especially to meet the needs of the electro-chemical, hydro-electric, dye and steel industries on the Niagara frontier, was dedicated on October 27 in connection with the installation of Dr. Samuel P Capen, of Washington, as chancellor of the university. Dr. Edgar F. Smith, president of the American Chemical Society, and Dr. Edwin E. Slosson, of Science Service, were speakers at the ceremony The laboratory, erected at a cost of a million dollars, is the gift of O. E. Foster, of Buffalo.

IN the will of Prince Albert of Monaco, who died on June 26 last, there are several gifts for scientific purposes. His farm at Sainte Suzanne is left to the French Academy of Agriculture, and the wish is expressed that the estate should remain a place for agricultural experiments, to demonstrate what science can obtain from sterile lands. Dr. Jules Richard will receive 600,000 francs to enable him to complete literary and scientific works in progress, including the results of the oceanographic cruises and the preparation of the Bathymetric Chart of the Oceans. The proceeds of the sale of the yacht *Hirondelle*, all books and publications of a scientific nature, as well as certain personal effects, will go to the Oceanographic Institutes at Paris and Monaco, while the Institute of Human Paleontology in Paris is to receive any personal effects relating to the work carried on there. The Paris Academy of Sciences will receive a million francs, the income of which is to provide a prize to be awarded every two years, the nature of the prize to be indicated by the academy, according to the needs of the moment; a like sum is bequeathed to the Academy of Medicine for a similar prize.

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